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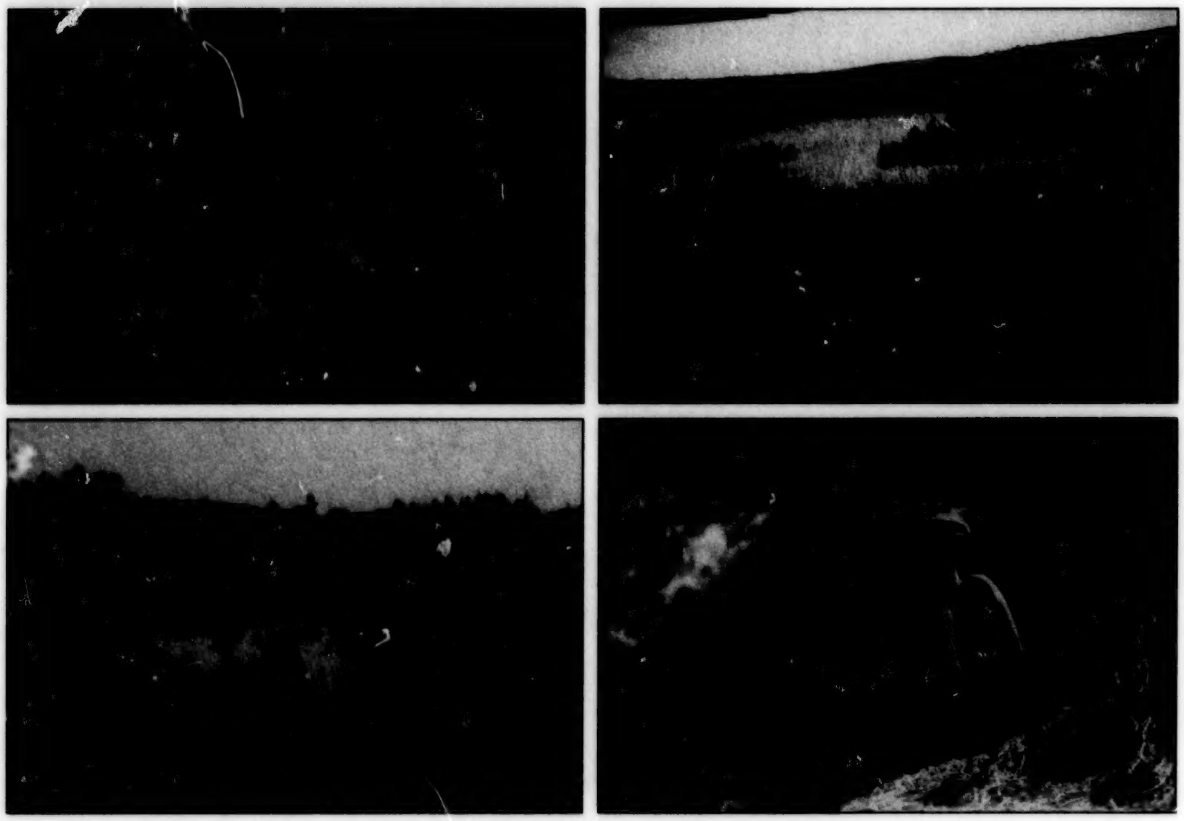
Fish and Wildlife Research 9

Use of Wetland Habitats by Selected Nongame Water Birds in Maine



UNITED STATES DEPARTMENT OF THE INTERIOR
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FISH AND WILDLIFE SERVICE
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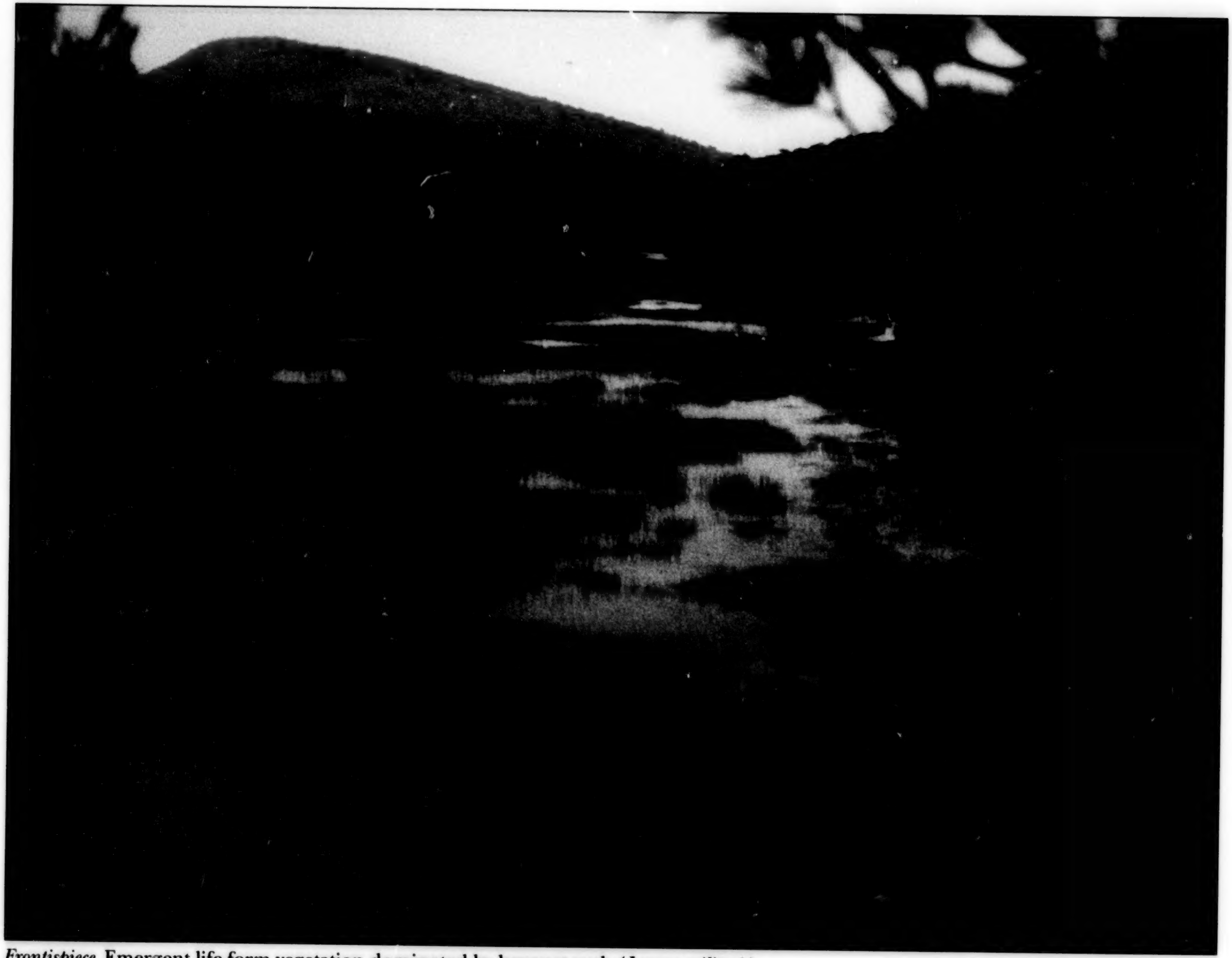

Frontispiece. Emergent life-form vegetation dominated by bayonet rush (*Juncus militaris*).

Use of Wetland Habitats by Selected Nongame Water Birds in Maine

by

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Abstract. We examined the use of 87 palustrine and lacustrine wetlands by nongame water birds in central and eastern Maine using 3,527 h of observation (1,501 visits) made during April–August, 1977–85. Wetlands used by 15 species of water birds were distinguished from those not used, according to 20 habitat features. The species were the common loon (*Gavia immer*), pied-billed grebe (*Podilymbus podiceps*), double-crested cormorant (*Phalacrocorax auritus*), American bittern (*Botaurus lentiginosus*), great blue heron (*Ardea herodias*), green-backed heron (*Butorides striatus*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), northern harrier (*Circus cyaneus*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), spotted sandpiper (*Actitis macularia*), common snipe (*Gallinago gallinago*), herring gull (*Larus argentatus*), and belted kingfisher (*Ceryle alcyon*). Predictive models of habitat use were developed for each species. Water birds were classified by similarity of habitats used, and species use was contrasted by wetland type.

Smaller, isolated wetlands were used by fewer ($P < 0.05$) species than larger wetlands in complexes; many species had large area-requirements (pied-billed grebe, common loon,

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herring gull, double-crested cormorant, bald eagle) or preferred to use wetlands near other wetlands (common loon, herring gull, great blue heron, spotted sandpiper, osprey, bald eagle). Wetland area contributed more to overall variation in species richness on wetlands than wetland isolation, although on small wetlands (≤3.6 ha) isolation was a better predictor of species richness than wetland area. Wetlands with intermediate amounts (33–66%) of emergent vegetation supported more species ($P < 0.05$) than closed (>66%) or open (<33%) wetlands. Low pH typified wetlands used by large-bodied piscivores (common loon, cormorant, osprey). Other water birds were associated with more densely vegetated, chemically buffered wetlands. Habitat features associated with wetland use by each waterbird species are reported, as are numerical responses of waterbird populations to wetland features and estimates of annual variation in habitat occupancy. Lacustrine wetlands supported a distinct, low diversity community of water birds, including most fish-eating species. Waterbird diversity at forested palustrine wetlands was intermediate between lacustrine communities and more species-rich assemblages at palustrine emergent and scrub–shrub wetlands. Regional variation in wetland characteristics and water bird use was associated with surficial geology, soils, and management practices. Management for nongame water birds in Maine should consider providing emergent and aquatic-bed vegetation with variable cover-to-water ratios, accommodating species-specific habitat needs, focusing on species of restricted distribution and low abundance, and maintaining wetland complexes. Bird use and habitat information from 87 wetlands and models of habitat selection for each species are provided in appendixes.

Key words: Wetlands, nongame birds, habitats, common loon, pied-billed grebe, double-crested cormorant, American bittern, great blue heron, green-backed heron, osprey, bald eagle, northern harrier, Virginia rail, sora, spotted sandpiper, common snipe, herring gull, belted kingfisher.

Wetlands are among the most productive and diverse of avian habitats. About one-third of North America's avifauna uses wetlands, and three-fourths of those are nongame species (Kroodsma 1978). Nongame birds that inhabit wetlands are of considerable ecological importance, both to the functioning of wetland ecosystems (Kushlan 1978) and as biological indicators of environmental quality (Custer and Osborn 1977). Wetlands in North America, however, continue to be altered or destroyed by human activities at an alarming rate. Less than half of the original wetland in the conterminous United States now exists and losses of wetland area continue at a rate of >160,000 ha/year (Tiner 1984). Inland freshwater wetlands are among the most threatened (Eddleman et al. 1988; Jorde et al. 1989) and about half of the migratory, nongame bird populations that are threatened or declining in the northeastern United States depend on these wetlands (U.S. Fish and Wildlife Service 1987).

Key environmental features that affect the distributions of species must be identified to assess the effects of human disturbance or habitat management on wetland bird communities (Kroodsma 1978). Considerable information has accrued on habitat relations of aquatic game birds, especially waterfowl (Ratti et al. 1982), but few data exist for nongame species (Brown and Dinsmore 1986; Fredrickson and Reid 1986; Swift 1987). Habitat information for nongame birds (Fig. 1) is needed to prepare environmental impact statements, to evaluate permits for wetland alteration, and for management of wildlife habitats (Golet 1978).

In this report, we summarize results of waterbird surveys conducted in 1977–85 at 87 palustrine and lacustrine wetlands in central and eastern Maine. Objectives of these analyses were to

- describe wetland habitats available to breeding, nongame birds in central and eastern Maine;
- identify wetland features most closely associated with distribution and abundance of 15 species of nongame water birds and develop predictive models of habitat selection for these species;
- contrast species use of different types of wetlands classified according to criteria of the national (Cowardin et al. 1979) and state of Maine (McCall 1972) wetlands inventories;
- examine effects of wetland acidity, area, isolation, habitat diversity, and cover-to-water interspersion

Fig. 1. Northern saw-whet owl use of dead snag as day roost in Flooded Timber life-form. *Photo by J. R. Longcore.*

on communities of nongame water birds; and

- provide a compilation of bird use and habitat data for individual wetlands that can serve as a reference for monitoring future population and habitat changes in Maine.

Study Areas

Wetlands were studied in four physiographically distinct regions of eastern and central Maine (Fig. 2). The 151-km² Dixmont study area is located in southern Dixmont and northern Monroe townships, 69° 5' W longitude, 44° 40' N latitude (1955 U.S.G.S., Brooks Quadrangle, 15-min series). The geology of the Monroe–Dixmont area is glacial till and topography consists of rolling hills (up to 370 m elevation). Soils are shallow to deep, well drained (Ringelman 1980), and more fertile than soils in the other study areas. Wetlands ($n = 26$) in the Dixmont area were studied between 1977 and 1980.

The 66-km² Cherryfield study area is located mostly in Township 10 S D, 68° 5' W longitude, 44° 40' N latitude, about 20 km west of Cherryfield,

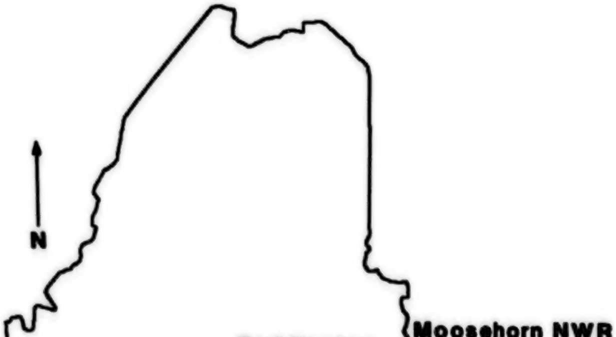

Fig. 2. Dixmont (151 km²), Beddington (25 km²), Cherryfield (66 km²), and Moosehorn National Wildlife Refuge (112 km²) study areas used to assess wetland habitats of nongame water birds during the breeding season in Maine, 1977–85.

Maine (1957 U.S.G.S., Tunk Lake Quadrangle, 15-min series). The area's surficial geology is a combination of extensive granitic bedrock and glacial till. Soils are thin loams.

The 25-km^2 Beddington study area is located in Township 30 M D, 67° 50' W longitude, 44° 55' N latitude, about 13 km east of Beddington, Maine (1941 U.S.G.S, Tug Mountain Quadrangle, 15-min series). Glacial till dominates surficial geology in this area and soils are sandy and gravelly. Wetlands ($n = 29$) were studied in Beddington and Cherryfield in 1982–84.

The 112 km^2 Moosehorn National Wildlife Refuge (NWR) is located in the towns of Calais, Baring, and Edmunds, Maine, 67° 15' W longitude, 45° 5' N latitude (1929 U.S.G.S., Calais Quadrangle, 15-min series). Moosehorn NWR is underlain by granitic bedrock and soils are thin loams similar to those in the Cherryfield area. Moosehorn NWR wetlands ($n = 32$) were studied in 1983–85.

All areas were located within the Northern Hardwoods Forest section of the Laurentian Mixed Forest Province (Bailey 1978). Upland sites at all areas are dominated by mixed hardwood–softwood stands and by pure coniferous stands on poorer soils. Winters are moderately long and severe and snow cover lasts from November to March. Average annual temperatures range from 10.2 to 22.2° C and precipitation ranges from 60 to 115 cm per year.

Methods

Physical and Chemical Characteristics of Wetlands

Wetlands were characterized by size, morphometry, vegetation, and spatial relations (Table 1). Black and white aerial photographs (Scale 1:7,900–15,840) were used to prepare base maps of major features and vegetational life-forms for each wetland. Base maps, enlarged and verified through on-site inspection, were the source of distance and areal measures. Many variables measured (Table 1) were related to percent and amount (ha) of surface water covered by different vegetative life-forms. The distance from a wetland's edge to the nearest road was measured as an index of potential human disturbance. Juxtaposition of wetlands was described by measuring interwetland distance. Wetland shoreline development, surface water irregularity, and life-form diversity characterized habitat diversity and amount of water-to-vegetation edge within a wetland. Distance to the nearest marine habitat (km) was measured and included in habitat descriptions for the herring gull and double-crested cormorant, whose nesting populations in Maine are largely associated with marine environments (Adamus 1987).

During studies in each area, water quality was assessed at least once for each wetland by determining specific conductance (an overall measure of the nutrient content of water) and pH. Each wetland was visited in June or July during the study periods to obtain water samples. Samples were collected in 300-ml polyethylene bottles that had been acid-washed and rinsed with deionized water. Samples were taken from midpond or in front of beaver dams at 35 cm below the surface. Water samples were cooled on ice and analyzed within 24 h after collection. Specific conductance (μmho/cm) and pH were measured with portable, calibrated meters.

Bird Use of Wetlands

Use of wetlands by birds was determined by repeatedly visiting wetlands for 2–3 h periods and recording the number of individuals and times each species was observed. To minimize disturbance to birds, investigators used elevated platforms concealed at wetland margins. Visits usually started 0.5 h before sunrise or 1.5 h before sunset and lasted 2 h. Observers recorded the date and beginning and ending times of visits, from which the number of visits and total hours of observation were calculated for each wetland. Wetlands were visited in random order four or more times per season. On large or irregularly-shaped wetlands, as many as eight persons surveyed an area simultaneously to ensure observational coverage of a wetland. Occasional overlap in species observation was reconciled among observers by comparing times of species occurrence and deleting duplicate observations. Visits were made during April–August (mostly May–July; Fig. 3) in conjunction with breeding pair and brood surveys for ducks; thus, observations sampled, primarily, usage of wetlands by breeding birds and, secondarily, by postbreeding and migrant birds.

All species seen or heard during wetland visits were recorded, but statistical analyses were restricted to species that breed in Maine (Adamus 1987), were obligate wetland associates, and were observed on five or more wetlands. Songbirds were excluded from analyses because populations could not be adequately surveyed from tree-stands.

Table 1. *Variables used to describe the physical characteristics of study wetlands.*

Variable	Mnemonic	Description or definition
Wetland area	AREA	Area (ha) covered by water ≥0.1 m depth
Shoreline development	SHOREDEV	Linear distance around perimeter of surface water (m)
Surface water, open	OPEN(%), OPEN(HA)	Percentage and area (ha) of surface water that is open (unvegetated)
Surface water, aquatic-bed	AQUAT(%), AQUAT(HA)	Percentage and area (ha) of surface water in submergent and floating-leaved vegetation (e.g., *Potamogeton, Nuphar, Fissidens, Drepanocladus*)
Surface water, emergent	EMERG(%), EMERG(HA)	Percentage and area (ha) of surface water in emergent vegetation (e.g., *Typha, Carex, Pontedaria*)
Surface water, ericaceous	ERIC(%), ERIC(HA)	Percentage and area (ha) of surface water in ericaceous vegetation (e.g., *Chamaedaphne, Myrica, Kalmia*)
Surface water, alder–willow	ALDR(%), ALDR(HA)	Percentage and area (ha) of surface water in alder–willow vegetation (e.g., *Alnus, Salix*)
Surface water, flooded timber	TIMB(%), TIMB(HA)	Percentage and area (ha) of surface water in flooded timber (e.g., *Abies, Picea, Acer*)
Life-form diversity	LFDINDX	An index of life-form diversity based on information theory (Lloyd et al. 1968)
Surface water irregularity Index	SWIINDX	An index of irregularity of the surface water perimeter calculated as the ratio of surface water perimeter to the perimeter of a circle with an area equal to that of the surface water
Interwetland distance	IWDIST	Linear distance between the edge of one wetland and the closest neighboring wetland (m)
Distance to road	RDDIST	Linear distance between a wetland and the nearest actively traveled road (m)

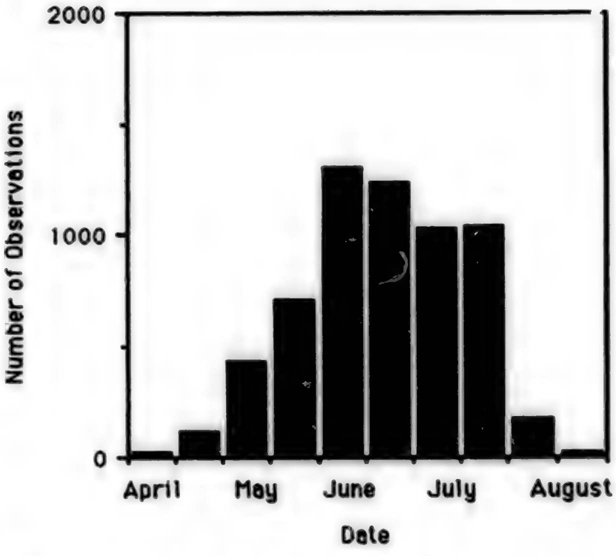

Fig. 3. Temporal distribution of the 6,018 observations of nongame water birds collected in central and eastern Maine, 1977–85. Months are divided into two periods: days 1–15 and ≥16.

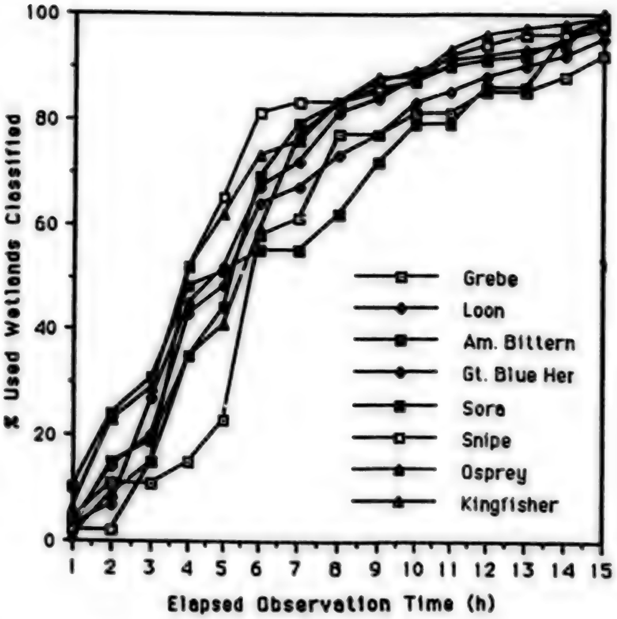

Fig. 4. Elapsed time from start of first visit to first sighting of a species on used wetlands versus cumulative percent of used wetlands classified.

Used and Unused Habitat Classification

One objective was to identify wetland features important in distinguishing between habitats that were used and those unused by each species. Johnson (1981) noted the difficulty of assigning habitats to used and unused categories because unused habitats may be suitable but simply unoccupied at the time of the study (also see Van Horne 1983), or a species may be present but not detected. We determined the minimum extent of observation needed to confirm, with reasonable certainty, the presence or absence of each species on a wetland. By plotting elapsed time from the start of the first visit to the first sighting of a species on used wetlands versus the cumulative percent of used wetlands (Fig. 4), we estimated that ≥10 h of observation was adequate to confirm use or nonuse by most species. Therefore, in our analyses we include only wetlands that received ≥10 h of observation and for which habitat and water chemistry data were available ($n = 87$ wetlands). Most wetlands received considerably more observation ($\bar{x} = 40.5$ h ± 48.6 SD) than the 10 h minimum. Wetlands with ≥10 h of observation tended to have greater wetland area than those excluded from the analysis (Fig. 5); however, in terms of total area, the subsample was representative of the size class distribution of wetlands on study areas (Fig. 5).

Because observational effort varied among wetlands, use was standardized as number of individuals seen per 100-h effort. Data from all years were pooled for each wetland. Wetlands with a species sighting frequency ≥1 individual per 100-h observation were considered used, others were considered unused. An observation of a bird that only flew over a wetland was excluded.

Inferring Habitat Selection for Each Species

Habitat preference for each species was inferred by comparing characteristics of used and unused wetlands with univariate tests. We used Mann–Whitney *U*-tests because few variables were normally distributed (Wilks–Shapiro tests, SAS Institute 1987). Wetlands of glacial origin (Fig. 6) and beaver-created (Fig. 7) and human-built impoundments have different characteristics (Naiman et al. 1986), so we examined distributions of used and unused wetlands and water bird sighting frequencies within these categories using Fisher exact probability tests (Zar 1984). We also examined numerical response of populations to each wetland feature. Sighting frequency (individuals per 100-h observation) of each species on used wetlands was compared with each wetland variable using Spearman rank correlation (Zar 1984). We examined annual variation in wetland occupancy

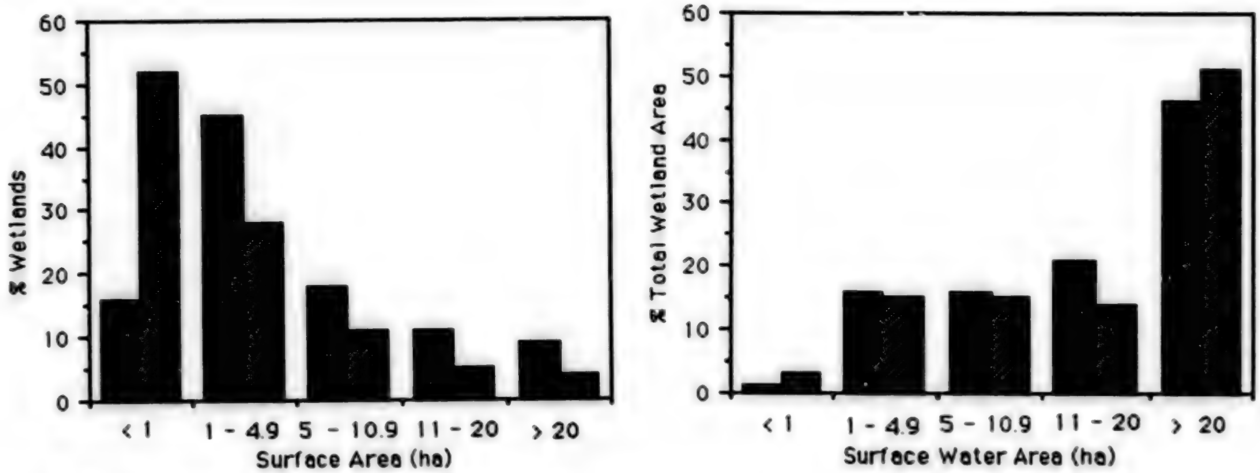

Fig. 5. Size distribution and percent total area of 212 wetlands in the four study areas (*hatched bars*) in central and eastern Maine and of 87 wetlands with ≥10 h of observation that were included in our analyses (*solid bars*).

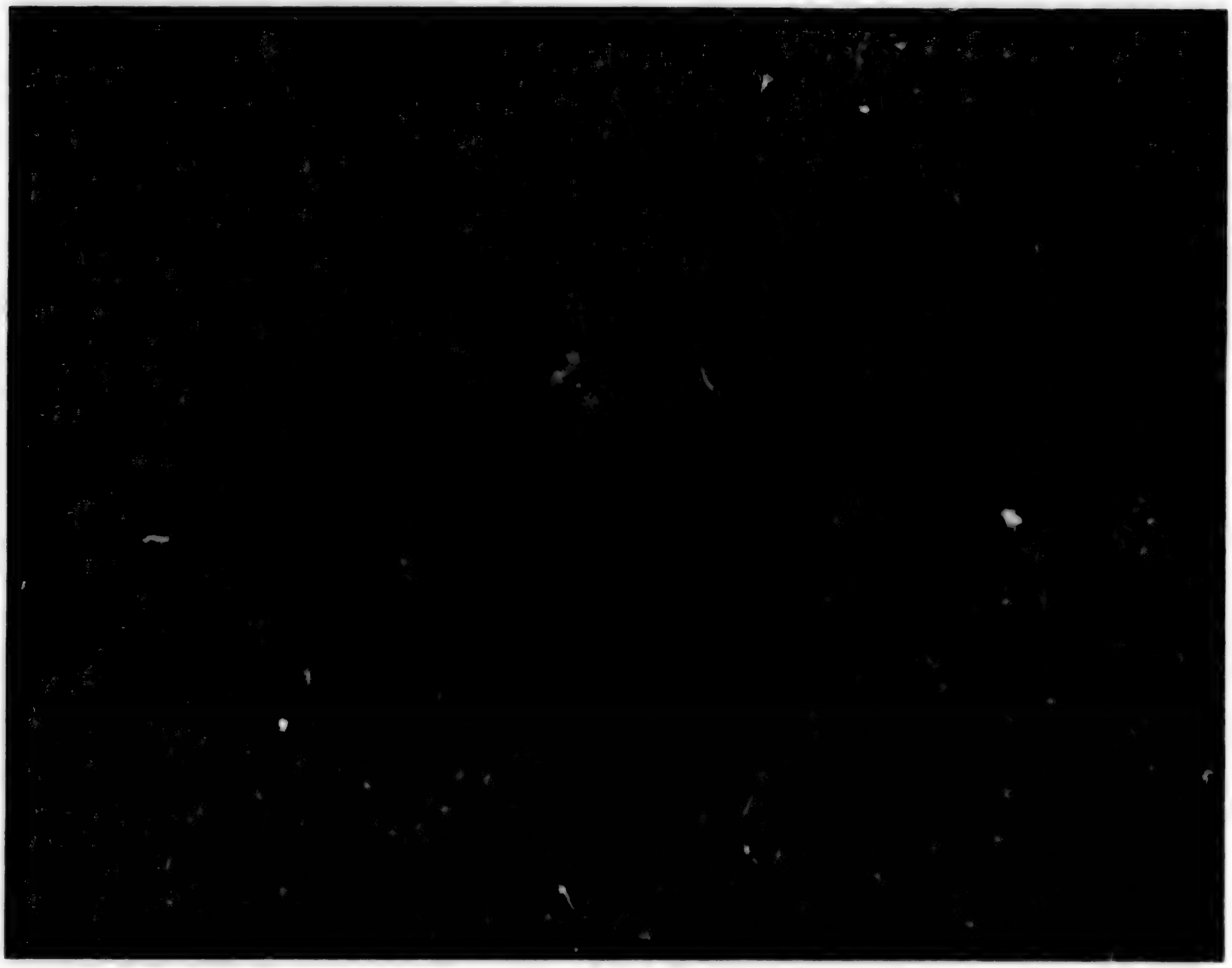

Fig. 6. Deep, bog ponds that are often acidic and lack vegetation receive little use from most marsh birds. *Photo by J. K. Ringelman.*

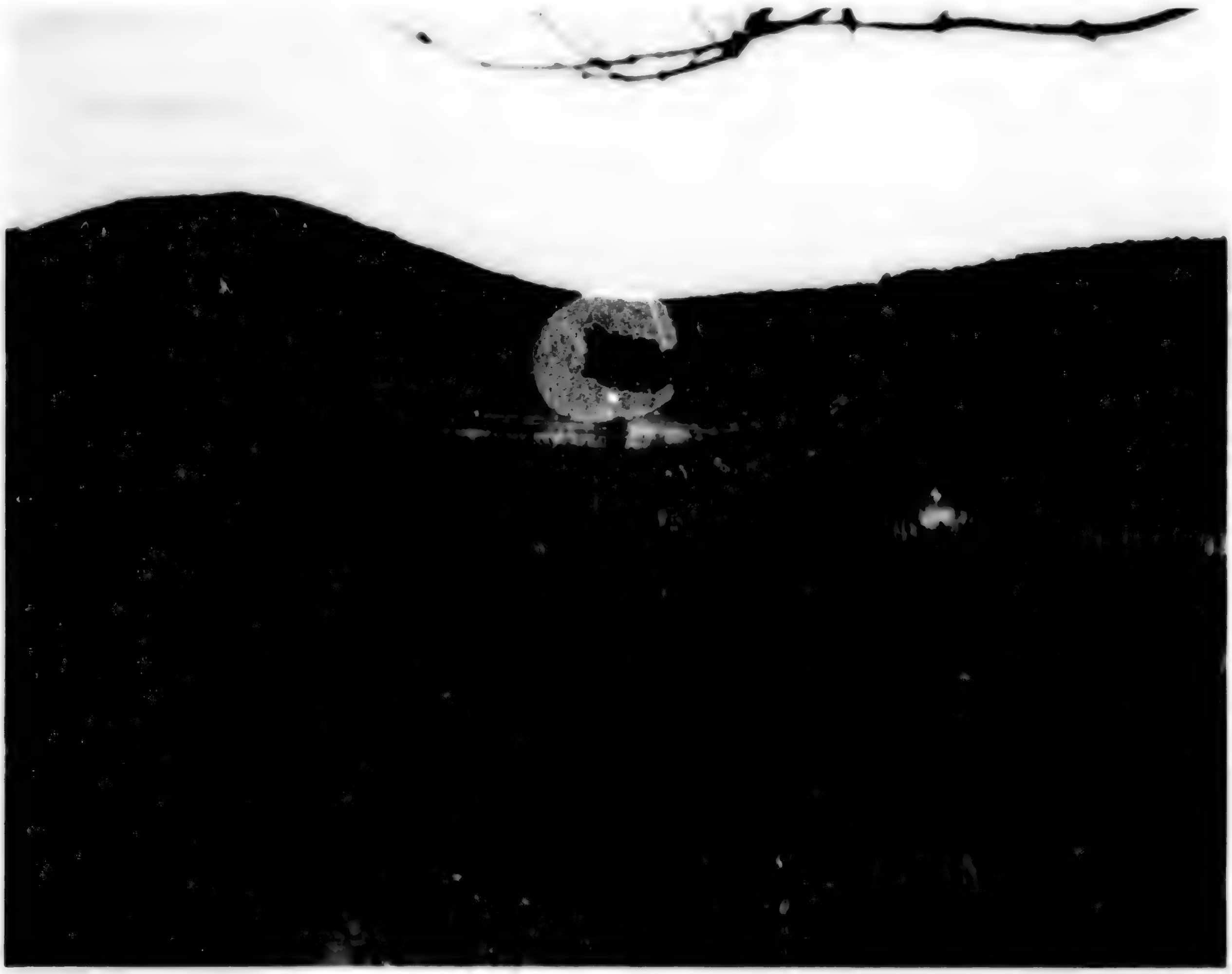

Fig. 7. Wetlands dominated by emergent life-form vegetation and influenced by beaver (*Castor canadensis*) provide nesting and foraging sites for several nongame marsh birds (herons, bitterns, rails). *Photo by J. R. Longcore.*

by determining, for each species at wetlands used during ≥1 year, the proportion of years those wetlands were occupied.

Development of Predictive Models of Habitat Selection for Each Species

Because ecological phenomena often are nonlinear (Johnson 1981) and data for wildlife habitats are rarely distributed normally (Green 1979), we developed logistic regression models of wildlife habitat selection. Logistic regression models do not assume multivariate–normal distribution of data or linear relation between variables and may provide better rates of between-group separation and classification than do linear models (e.g., discriminant function analyses; Brennen et al. 1986). Additionally, logistic models can be readily implemented and interpreted by biologists and managers. We therefore used logistic regression to examine the relation between the probability that a wetland was used by a given species and characteristics of that wetland according to the function

$$P = e^y/1+e^y$$

where P = the probability (0–1) that a wetland will be used by a species and $y = a + \beta_1 X_{1i} + \ldots B_m X_{mi}$ (where a = a constant, β = the regression coefficient, and X = predictor variables in the model). Prior probabilities (proportion of wetlands with a given species present) can be used as cutpoints to classify use or nonuse of wetlands. For example, if American bitterns (*Botaurus lentiginosus*) occurred on 53% of the wetlands in an area, wetlands with *P*-values from habitat models exceeding 0.53 likely support American bitterns.

To minimize interference associated with co-linearity among descriptor variables, only the variable from correlated ($r > 0.60$) pairs that contributed most to the separation between used and unused wetlands in the univariate comparisons was entered into each model. Thus, different sets of variables were used to develop three habitat models for each species. The first model consisted of all uncorrelated habitat and water chemistry variables, the second, only habitat variables (because water chemistry data may not always be available), and the third was a reduced-variable model (stepwise logistic regression procedure, SAS Institute 1983) including the best set of predictor variables. A model fit to these data was assessed by examining the log–likelihood ratio, of which values >0.05 for all species indicated an adequate fit (Smith and Connors 1986). *P*-values <0.05 for regression coefficients were accepted for individual habitat variables as significant predictors of water bird use of wetlands. We determined, for each species, the proportion of study wetlands classified correctly by models as used or unused habitat. Model validation, however, is not possible until an independent set of observations becomes available.

Description of Wetland Habitats Available to Water Birds

Wetland data were reduced to express the major underlying relations between the descriptor variables (Table 1) by using principal components analysis with a VARIMAX rotation method (SAS Institute 1987). Percentage data were normalized by arcsine transformation, and all other data (except pH) were log-transformed. All variables were standardized and two wetlands of extreme size were excluded from the analysis, yielding a data set of 85 wetlands.

Interpretation of principal component axes can be complicated by high correlations among descriptor variables. This commonly occurred in our data set between relative and absolute measures of the same wetland feature (e.g., between percent surface water in emergent vegetation and area of emergent vegetation). Therefore, separate principal component analyses were performed on variable sets consisting of either relative or absolute habitat measures. We present results from the relative variable set, because the first three principal components retained from this data set explained more variance in these data and were biologically more meaningful than those retained from the absolute variable set. We interpreted correlations (adj. r^2) ≥0.36 between habitat variables and principal components.

Influence of Cover-to-Water Ratios and Wetland Size–Isolation–Diversity on Species Richness

We evaluated whether wetlands with intermediate (33–66%) emergent cover were used by a greater number of species (from the assemblage studied) than wetlands with either more or less emergent cover (cf. Weller and Spatcher 1965). Differences in species richness on wetlands in different classes of emergent cover were evaluated with the Kruskal–Wallis test (Zar 1984). The relations between species richness of water birds and wetland area, isolation, and habitat diversity (life-form diversity index) were examined by using a multiple, linear regression procedure (Zar 1984). Area and isolation were log-transformed before analysis.

Contrasting Bird Use by Wetland Types

We contrasted species use of various wetland types as classified by criteria of Cowardin et al. (1979) and the Maine Wetlands Inventory (McCall 1972). Under the procedures of Cowardin et al., each wetland was classified at the system, class, and subclass level. At the class level, wetlands were recognizable according to the dominant (≥30% areal coverage of the entire wetland) vegetative life-form. J. R. Longcore, who is familiar with wetlands, classified the study wetlands using the state of Maine system according to McCall's qualitative descriptions. Bird communities at different wetland types were contrasted in terms of species richness, sighting frequency, and probability of visit by each species.

Results and Discussion

Species Included in Analyses

Data for 15 species were compiled and analyzed. The species are the common loon (*Gavia immer*), pied-billed grebe (*Podilymbus podiceps*), double-crested cormorant (*Phalacrocorax auritus*), American bittern (*Botaurus lentiginosus*), great blue heron (*Ardea* *herodias*), green-backed heron (*Butorides striatus*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), northern harrier (*Circus cyaneus*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), spotted sandpiper (*Actitis macularia*), common snipe (*Gallinago gallinago*), herring gull (*Larus argentatus*), and belted kingfisher (*Ceryle alcyon*). All were nongame species except the Virginia rail, sora, and common snipe, included in the analyses because they are common marsh-inhabiting species for which habitat information is scarce (Fogarty and Arnold 1977; Eddleman et al. 1988). The least bittern (*Ixobrychus exilis*), common moorhen (*Gallinula chloropus*), and American coot (*Fulica americana*) usually reach the northern limit of their ranges in Maine but were not observed during our studies. Likewise, black-crowned night-herons (*Nycticorax nycticorax*) and common terns (*Sterna hirundo*) were not observed. Black terns (*Chlidonias niger*) were observed at a single, lacustrine site.

Habitat Use and Selection by Waterbird Species

Common Loon

The common loon used 36 (41%) of the wetlands studied. Wetlands used had lower pH and conductivity than unused (Table 2). Although low pH and conductivity are associated with decreased fish abundance (Almer et al. 1974; Ryder et al. 1974; McNicol et al. 1987), reduced pH may benefit fish-eating birds that pursue prey underwater by increasing prey visibility and capture success (Eriksson 1985; DesGranges and Houde 1989). Decreased coverage by emergent vegetation on used wetlands (Table 2) may be indirectly related to selection by loons of deep, lacustrine wetlands with transparent waters.

Table 2. *Characteristics of wetlands not used and used by common loons (*Gavia immer*) during the breeding season in Maine, 1977–85 (see Table 1 for complete descriptions of variables).*

Variable	Unused $n = 51$ $\bar{x} \pm$ SD	Used $n = 36$ $\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.35 ± 1.02	0.03 ± 0.16	0.05
Alder (%)	6.83 ± 18.54	0.31 ± 0.96	0.05
Aquatic-bed (ha)	0.40 ± 0.96	2.04 ± 3.39	0.01
Aquatic-bed (%)	16.02 ± 22.11	28.40 ± 35.57	N.S.
Emergent (ha)	2.09 ± 4.52	1.67 ± 2.68	N.S.
Emergent (%)	34.26 ± 30.34	21.66 ± 26.63	0.05
Ericaceous (ha)	1.48 ± 7.21	0.41 ± 1.17	N.S.
Ericaceous (%)	5.54 ± 10.98	4.69 ± 11.64	N.S.
Timber (ha)	0.97 ± 4.78	0.13 ± 0.38	N.S.
Timber (%)	6.81 ± 17.66	4.80 ± 14.40	N.S.
Open water (ha)	1.25 ± 1.76	6.36 ± 7.12	0.001
Open water (%)	33.10 ± 33.19	52.40 ± 37.67	0.05
Life-form diversity	1.56 ± 0.73	1.49 ± 0.83	N.S.
Surface water			
Area (ha)	7.18 ± 18.03	9.95 ± 8.20	0.001
Irregularity	2.72 ± 1.51	2.56 ± 1.42	N.S.
Perimeter (m)	2,030.65 ± 2,147.04	2,493.11 ± 1,908.68	N.S.
Spatial relations			
Interwetland distance (m)	521.21 ± 474.07	335.40 ± 457.22	0.05
Distance to road (m)	706.19 ± 585.74	1,205.51 ± 1,045.36	0.05
Water chemistry			
pH	6.52 ± 0.66	6.20 ± 0.56	0.01
Conductivity	53.30 ± 63.59	29.13 ± 10.84	0.001

[a] *P*-values calculated by Mann–Whitney *U*-tests; N.S. = not significant.

Beds of emergent vegetation often provide large amounts of nutrients to adjacent open water ecosystems (Moss 1980) that reduce water transparency. Increased distance to roads may reflect selection of wetlands isolated from sources of human disturbance (Vermeer 1973).

Loons require a long stretch of open water to take flight. Wetlands used by loons in our study showed a fivefold increase in area of open water in comparison to unused wetlands (Table 2). Although more than three-fourths of the wetlands used by loons in our study areas were >20 ha, some loons occasionally used small (<1 ha) wetlands (Fig. 8). The decreased interwetland distance associated with used wetlands (Table 2) may reflect use of alternate wetlands for foraging by loons (see Parker and Brocke 1984).

Loons using large lakes in Maine preferred to forage in water 1.1–4.0 m deep and 51–150 m from land (Strong 1985; Strong and Bissonette 1989). They avoided extremely shallow areas near wetland margins and deep waters far from land. In Quebec, however, loons frequented large, deep, low-altitude lakes of moderate acidity and poorly developed riparian vegetation (DesGranges and Darveau 1985; DesGranges and Houde 1989).

Adults catch large numbers of small fish and insects that chicks can swallow whole (Strong 1985). Aquatic-bed vegetation, more abundant on used than on unused wetlands (Table 2), is rich in invertebrates, small fish, and edible plants (Voigts 1976; Ringelman 1980) and may represent an important source of food for adult loons to feed chicks. Floating-leaved and submerged plants are common in shallow, sheltered areas frequented by chicks (McIntyre 1983). Small patches of emergent and ericaceous vegetation along margins of used wetlands (Table 2) may provide nesting habitat for loons.

The sighting frequency of loons on used wetlands was related negatively to percent of wetland area in emergent vegetation ($r_s = -0.37$, $P < 0.05$) and related positively to area of open water ($r_s = 0.55$, $P < 0.001$), implying that more birds were seen on larger, less vegetated ponds. Abundance and species richness of fish communities on 22 lakes <50 ha were positively related to lake area (Haines et al. 1986), and use of larger wetlands by loons may reflect greater prey abundance at these wetlands. Wetlands of glacial origin (22.4 loons per 100 h) were used more frequently ($P < 0.05$) than beaver-created wetlands or human-created impoundments (2.1 loons per 100 h). Common loons occupied used wetlands (used ≥1 year) 65% of the total years of study. Models of habitat selection by common loons are presented in Table A-1.

Pied-billed Grebe

The pied-billed grebe occurred on 15 (17%) of the wetlands. Wetlands used by grebes had more aquatic-bed vegetation (floating-leaved and submerged plants), ericaceous vegetation, and emergent vegetation than did unused (Table 3). Morphological features of used wetlands included large wetland area and shoreline development (Table 3). Pied-billed grebes were sensitive to wetland size and were not observed on wetlands <5 ha (Fig. 8). Similarly, pied-billed grebes in Iowa rarely occurred on wetlands <5 ha (Brown and Dinsmore 1986). The rela-

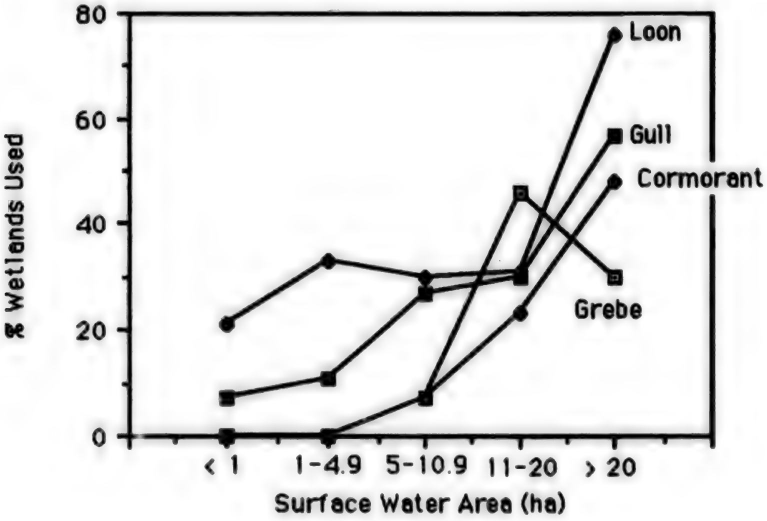

Fig. 8. Percent occurrence by wetland size for common loon (*Gavia immer*), pied-billed grebe (*Podilymbus podiceps*), double-crested cormorant (*Phalacrocorax auritis*), and herring gull (*Larus argentatus*).

Table 3. *Characteristics of wetlands not used and used by pied-billed grebes (*Podilymbus podiceps*) during the breeding season in Maine, 1977–85 (see Table 1 for complete descriptions of variables).*

	Unused	Used	
	$n = 72$	$n = 15$	
Variable	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	P[a]
Vegetative life-forms			
Alder (ha)	0.14 ± 0.47	0.63 ± 1.69	N.S.
Alder (%)	4.47 ± 15.70	2.86 ± 7.19	N.S.
Aquatic-bed (ha)	0.60 ± 1.48	3.46 ± 4.30	0.001
Aquatic-bed (%)	16.77 ± 26.05	43.07 ± 33.01	0.001
Emergent (ha)	1.69 ± 3.23	3.14 ± 6.29	0.05
Emergent (%)	31.75 ± 30.97	15.84 ± 13.40	N.S.
Ericaceous (ha)	0.29 ± 1.09	5.03 ± 13.51	0.05
Ericaceous (%)	3.77 ± 8.87	12.64 ± 17.92	0.05
Timber (ha)	0.17 ± 0.53	3.01 ± 9.07	N.S.
Timber (%)	5.96 ± 16.68	6.21 ± 15.21	N.S.
Open water (ha)	3.12 ± 5.57	4.28 ± 3.72	N.S.
Open water (%)	42.01 ± 37.33	34.86 ± 29.45	N.S.
Life-form diversity	1.49 ± 0.80	1.76 ± 0.55	N.S.
Surface water			
Area (ha)	5.96 ± 7.28	20.46 ± 31.31	0.001
Irregularity	2.56 ± 1.43	3.19 ± 1.57	N.S.
Perimeter (m)	1,900.38 ± 1,789.32	3,866.07 ± 2,594.74	0.001
Spatial relations			
Interwetland distance (m)	426.56 ± 465.38	550.21 ± 520.22	N.S.
Distance to road (m)	827.90 ± 781.05	1,319.86 ± 1,003.92	N.S.
Water chemistry			
pH	6.39 ± 0.64	6.38 ± 0.66	N.S.
Conductivity	44.82 ± 55.05	37.07 ± 16.55	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

tive abundance (sighting frequency) of grebes on used wetlands was inversely related to the percent of surface water in flooded timber ($r_s = -0.64$, $P < 0.05$). Pied-billed grebes used human- and beaver-created wetlands (7.8 grebes per 100 h) more frequently ($P < 0.05$) than those of glacial origin (0.2 grebes per 100 h). Pied-billed grebes occupied used wetlands (used ≥1 year) 59% of the total years of study.

Pied-billed grebes in Maine feed principally on invertebrates, plant material, and small fish (Palmer 1949), and are associated with aquatic-bed vegetation along the shallow margins of ponds. In contrast, pied-billed grebes in North Dakota tend to use larger ponds with heavy emergent vegetation (Faaborg 1976). Aquatic-bed and emergent vegetation, important sources of edible plants, are particularly rich in invertebrate foods used by grebes (Voigts 1976; Ringelman 1980). Pied-billed grebes are poorly buoyant and reluctant to fly (Bent 1963), and a preference for large wetlands may reflect the species' need to meet all its foraging requirements on a single wetland rather than flying to alternate sites at other wetlands. Models of habitat selection by pied-billed grebes are presented in Table A-2.

Double-crested Cormorant

Double-crested cormorants used 15 (17%) of the wetlands. They were sensitive to area, and the wetlands used were characterized by increased area (>5 ha; Fig. 8), shoreline development, and availability of open water (Table 4). Used wetlands had more aquatic-bed, ericaceous, and emergent vegetation than did unused (Table 4). Wetlands preferred by cormorants were more heavily vegetated, and presumably shallower, than those used by loons (Table 2). Cormorants used wetlands of glacial ori-

Table 4. *Characteristics of wetlands not used and used by double-crested cormorants* (Phalacrocorax auritus) *during the breeding season in Maine, 1977–85 (see Table 1 for complete descriptions of variables).*

Variable	Unused $n = 72$ $\bar{x} \pm$ SD	Used $n = 15$ $\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.26 ± 0.88	0.01 ± 0.02	N.S.
Alder (%)	5.07 ± 15.98	0.07 ± 0.26	N.S.
Aquatic-bed (ha)	0.57 ± 1.23	3.44 ± 4.51	0.01
Aquatic-bed (%)	18.40 ± 26.06	33.47 ± 37.89	N.S.
Emergent (ha)	1.26 ± 1.98	5.13 ± 7.69	0.05
Emergent (%)	29.54 ± 29.89	27.52 ± 27.93	N.S.
Ericaceous (ha)	0.46 ± 1.68	3.86 ± 13.04	0.05
Ericaceous (%)	4.47 ± 9.67	8.67 ± 16.71	N.S.
Open water (ha)	2.40 ± 4.16	7.68 ± 7.81	0.05
Open water (%)	40.83 ± 36.52	41.00 ± 35.41	N.S.
Timber (ha)	0.66 ± 4.00	0.47 ± 1.81	N.S.
Timber (%)	7.15 ± 17.78	0.47 ± 1.55	N.S.
Life-form diversity	1.53 ± 0.83	1.53 ± 0.41	N.S.
Surface water			
Area	5.64 ± 8.65	21.01 ± 27.76	0.001
Irregularity	2.59 ± 1.38	3.00 ± 1.83	N.S.
Perimeter	1,891.29 ± 1,759.07	3,778.67 ± 2,666.17	0.001
Spatial relations			
Interwetland distance (m)	478.62 ± 472.99	292.07 ± 461.01	N.S.
Distance to road (m)	852.44 ± 789.25	1,169.27 ± 1,014.03	N.S.
Marine distance (km)	16.06 ± 10.41	15.39 ± 10.16	N.S.
Water chemistry			
pH	6.44 ± 0.63	6.13 ± 0.61	0.05
Conductivity	46.52 ± 55.41	29.43 ± 7.59	0.05

[a] P- values calculated by Mann–Whitney U-tests; N.S. = not significant.

gin (3.8 cormorants per 100 h) and those created by humans or beaver (5.1 cormorants per 100 h) in equal proportion ($P > 0.05$). Conductivity and pH were lower on used than unused wetlands (Table 4) and the cormorants were more numerous on more acidic waters, the abundance inversely related with pH ($r_s = -0.64$, $P < 0.05$). Double-crested cormorants occupied used wetlands (used ≥1 year) 56% of the total years of study.

Cormorants using inland waters of Maine typically fed near the littoral (Palmer 1949). Use of shallow foraging areas may be related to an increased availability of emergent and aquatic-bed vegetation (Table 4) that provide cover and feeding areas for forage fish. The cormorant's diet in New England is predominantly fish [illegible] 1926) and, like other piscivores in this study, they used wetlands with lower pH and conductivity. Increased prey visibility and improved capture success may influence cormorant use of these wetlands (Eriksson 1985), although waters of most wetlands used were highly colored.

Models of habitat selection by double-crested cormorants are presented in Table A-3. Numbers of double-crested cormorants have increased rapidly in New England during the last 20 years (Korschgen 1979) and wetland selectivity and the proportion of wetlands used by cormorants may change substantially.

American Bittern

The American bittern occurred on 46 (53%) of the wetlands. Wetlands used were dominated by emergent and aquatic-bed vegetation and had increased diversity of vegetative life-forms (Table 5). Extensive interspersion of water and emergent vegetation was an important characteristic of wetlands used by the bitterns; used wetlands had less open water and longer shorelines than unused wetlands (Table 5). Abundance of American bitterns at used wetlands was related positively to wetland area ($r_s = 0.49$, $P < 0.001$), implying that bitterns were more abundant on larger than on smaller wetlands, but they inhabited wetlands of all sizes (Fig. 9). In comparison, their occurrence at Iowa marshlands was considered dependent on wetland area (Brown and Dinsmore 1986). They preferred ($P < 0.05$) impoundments and beaver-created wetlands (9.6 bitterns per 100 h) to those of glacial origin (0.3 bitterns per 100 h). American bitterns occupied used wetlands (used ≥1 year) 62% of the total years of study.

American bitterns take a wide variety of prey, including frogs (preferred), crayfish, insects, and small fish, and feed by walking slowly or standing and waiting (Kushlan 1976). Fredrickson and Reid (1986) noted that American bitterns using moist-soil impoundments in Missouri were associated with water depths ≤10 cm and vegetative cover ranging from sparse to rank. Bitterns in Quebec preferred lakes with numerous patches of floating-leaved plants, extensive growth of fine-leaved emergents along shorelines, and abundant amphibian populations (DesGranges and Houde 1989). Our data suggest that American bitterns in Maine prefer wetlands with a variety of vegetative life-forms, including extensive beds of fine- and broad-leaved (robust and coarse) emergent and aquatic-bed plants (Figs. 10 and 11), well interspersed with water (Table 5). Models of habitat selection by American bitterns are presented in Table A-4.

Table 5. *Characteristics of wetlands not used and used by American bitterns (*Botaurus lentiginosus*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 41$ $\bar{x} \pm$ SD	Used $n = 46$ $\bar{x} \pm$ SD	P[a]
Vegetative life-forms			
Alder (ha)	0.19 ± 0.61	0.25 ± 0.96	N.S.
Alder (%)	4.66 ± 17.02	3.80 ± 12.33	N.S.
Aquatic-bed (ha)	1.00 ± 2.88	1.11 ± 1.89	N.S.
Aquatic-bed (%)	13.15 ± 23.28	28.00 ± 31.51	0.05
Emergent (ha)	1.22 ± 2.31	2.55 ± 4.81	0.05
Emergent (%)	25.22 ± 31.29	32.73 ± 27.49	0.05
Ericaceous (ha)	0.21 ± 0.86	1.80 ± 7.66	N.S.
Ericaceous (%)	3.12 ± 8.28	7.04 ± 13.07	N.S.
Open water (ha)	4.77 ± 6.87	2.00 ± 2.89	N.S.
Open water (%)	54.37 ± 40.00	28.83 ± 27.52	0.01
Timber (ha)	0.12 ± 0.44	1.08 ± 5.07	N.S.
Timber (%)	4.34 ± 13.97	7.48 ± 18.27	N.S.
Life-form diversity	1.28 ± 0.60	1.76 ± 0.83	0.05
Surface water			
Area (ha)	7.13 ± 8.21	9.33 ± 18.99	N.S.
Irregularity	2.43 ± 1.38	2.86 ± 1.52	N.S.
Perimeter (m)	1,777.32 ± 1,513.51	2,608.33 ± 2,389.04	0.05
Spatial relations			
Interwetland distance (m)	371.44 ± 391.84	513.33 ± 531.54	N.S.
Distance to road (m)	827.71 ± 791.18	977.80 ± 873.57	N.S.
Water chemistry			
pH	6.23 ± 0.73	6.53 ± 0.51	N.S.
Conductivity	35.22 ± 17.08	51.02 ± 67.56	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

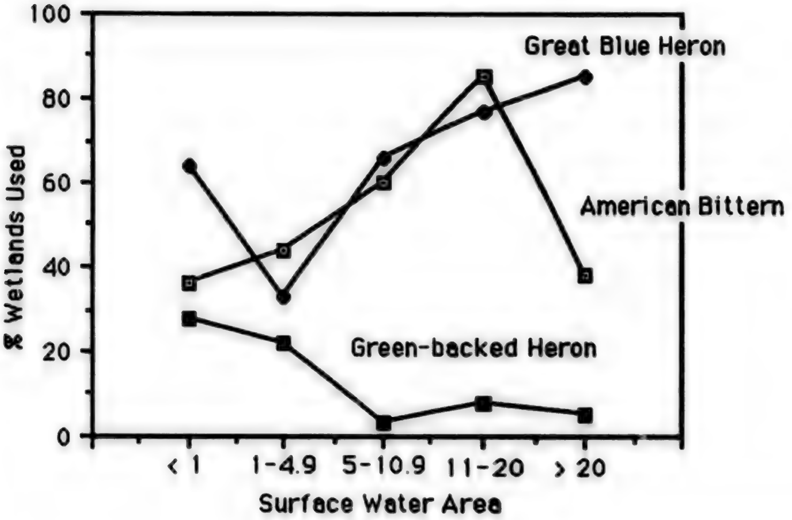

Fig. 9. Percent occurrence by wetland size for American bittern (*Botaurus lentiginosus*), great blue heron (*Ardea herodias*), and green-backed heron (*Butorides striatus*).

Fig. 10. Aquatic-bed life-form vegetation provides substrate for invertebrates and vertebrates for marsh-dwelling birds. *Photo by J. R. Longcore.*

Great Blue Heron

The great blue heron used 60 (69%) of the wetlands. Wetlands used by the herons contained more wetland area, more extensive beds of emergent vegetation, longer shorelines, and less open water than unused wetlands (Table 6). Great blue herons are littoral foragers that stand and wait or walk slowly in pursuit of prey (Kushlan 1976). The rates of secondary production in beds of emergent vegetation are among the highest observed in nonmarine ecosystems (Moss 1980), and cattail–sedge meadows may provide a rich prey-base for great blue herons in Maine. The herons foraged most intensively in emergent habitats along the shores of Lake Erie (Hoffman 1978) and the Upper Mississippi River (Thompson 1979). In southern Quebec they preferred large, low-altitude lakes with poorly developed riparian vegetation (DesGranges and Darveau 1985). Postbreeding great blue herons in Oklahoma frequented unmodified, natural palustrine wetlands and avoided farm ponds that lacked emergent and submergent vegetation (Heitmeyer 1986). The extensive shoreline and high degree of vegetation-to-water interspersion observed on used wetlands in this study (Table 6) might provide more foraging sites for the herons than occur on unused wetlands.

The abundance of great blue herons on used

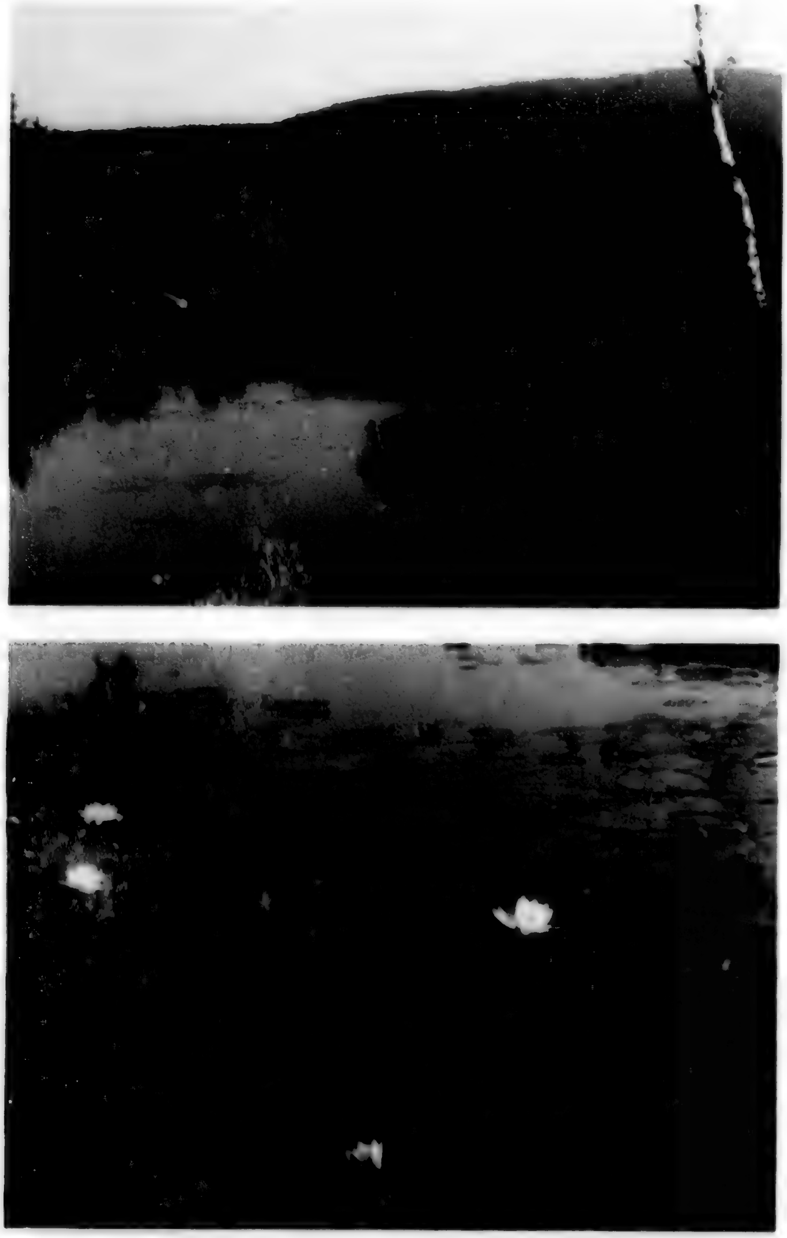

Fig. 11. Aquatic-bed life-form vegetation dominated by cowlily (*Nuphar* spp.) and waterlily (*Nymphaea* spp.). *Photo by J. R. Longcore.*

wetlands was positively correlated to the area of emergent vegetation ($r_s = 0.45$, $P < 0.01$), the area of aquatic-bed vegetation ($r_s = 0.37$, $P < 0.01$), the area of surface water ($r_s = 0.48$, $P < 0.001$), and the length of the shoreline ($r_s = 0.42$, $P < 0.001$). Heron abundance was negatively correlated with interwetland distance ($r_s = -0.31$, $P < 0.05$), implying that fewer were observed on isolated wetlands. Great blue herons preferred ($P < 0.001$) wetlands of beaver or human origin (82% of used wetlands, 16.2 herons per 100 h) to those of glacial origin (6.4 herons per 100 h). Glacial wetlands on our study areas had deep basins and reduced littoral. The great blue heron frequented small (<1 ha) wetlands, and use was independent of wetland size (Fig. 9). Great blue herons occupied used wetlands (used ≥1 year) 69% of the total years of study.

The abundance of great blue herons on used wetlands observed for ≥3 years ($n = 47$) was positively correlated with the number of years each wet-

Table 6. *Characteristics of wetlands not used and used by great blue herons* (Ardea herodias) *during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

	Unused	Used	
	$n = 27$	$n = 60$	
Variable	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.17 ± 0.41	0.24 ± 0.94	N.S.
Alder (%)	6.89 ± 17.63	3.00 ± 13.07	N.S.
Aquatic-bed (ha)	0.49 ± 1.09	1.32 ± 2.76	N.S.
Aquatic-bed (%)	17.85 ± 28.34	22.42 ± 29.07	N.S.
Emergent (ha)	0.46 ± 0.64	2.59 ± 4.50	0.001
Emergent (%)	22.07 ± 30.90	32.40 ± 28.40	0.05
Ericaceous (ha)	0.09 ± 0.23	1.48 ± 6.75	N.S.
Ericaceous (%)	2.04 ± 4.15	6.62 ± 12.97	N.S.
Open water (ha)	2.85 ± 5.21	3.51 ± 5.39	N.S.
Open water (%)	54.33 ± 38.74	34.80 ± 33.47	0.05
Timber (ha)	0.29 ± 0.75	0.78 ± 4.44	N.S.
Timber (%)	8.26 ± 21.24	4.98 ± 13.72	N.S.
Life-form diversity	1.43 ± 0.90	1.58 ± 0.70	N.S.
Surface water			
Area (ha)	4.07 ± 5.28	10.19 ± 17.28	0.01
Irregularity	2.32 ± 1.50	2.81 ± 1.44	0.05
Perimeter (m)	1,451.59 ± 1,354.87	2,561.00 ± 2,227.68	0.05
Spatial relations			
Interwetland distance (m)	575.74 ± 520.76	388.28 ± 443.15	N.S.
Distance to road (m)	995.52 ± 983.86	867.27 ± 763.52	N.S.
Water chemistry			
pH	6.35 ± 0.76	6.40 ± 0.58	N.S.
Conductivity	41.57 ± 24.65	44.48 ± 59.16	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

land was occupied by the species ($r_s = 0.66$, $P < 0.001$), implying that irregularly used wetlands had sparse populations of great blue herons. Proximity of a wetland to a nesting colony (not measured in this study) also may influence wetland use by herons. Herons tend to use wetlands near colonies more frequently than wetlands more distant from colonies (Custer and Osborn 1978). Models of habitat selection by great blue herons are presented in Table A-5.

Green-backed Heron

Green-backed herons occur in Maine at the northern edge of their range and were observed infrequently on five (6%) of the wetlands. For purposes of habitat description, all wetlands on which the herons were observed were included in the used wetland sample in this analysis ($n = 10$), although some received <10 h of observation. Green-backed herons preferred small wetlands with highly conductive water, near roads and with extensive alder–willow cover (Table 7). They typically forage by perching and waiting (Kushlan 1976). They frequent dense, woody vegetation (Fig. 12) bordering ponds, rivers, and lakes, and feed mainly on fish and insects (Hancock and Kushlan 1984). The association between green-backed herons and availability of shrub-growth observed in our study may result from the heron's need for elevated perches from which to hunt.

Most wetlands (90%) used by green-backed herons were of human or beaver origin. The sighting frequency on used wetlands was positively related to

Table 7. *Characteristics of wetlands not used and used by green-backed herons* (Butorides striatus) *during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 82$ $\bar{x} \pm$ SD	Used $n = 10$ $\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.22 ± 0.83	0.11 ± 0.24	N.S.
Alder (%)	3.49 ± 12.77	16.40 ± 31.05	0.05
Aquatic-bed (ha)	1.10 ± 2.46	0.21 ± 0.53	N.S.
Aquatic-bed (%)	21.37 ± 29.22	12.90 ± 18.47	N.S.
Emergent (ha)	1.91 ± 3.93	1.13 ± 2.35	N.S.
Emergent (%)	0.64 ± 2.45	6.64 ± 10.84	N.S.
Ericaceous (ha)	1.01 ± 5.75	1.62 ± 3.30	N.S.
Ericaceous (%)	4.38 ± 9.50	10.80 ± 18.84	N.S.
Timber (ha)	0.66 ± 3.82	0.05 ± 0.16	N.S.
Timber (%)	6.22 ± 16.80	1.20 ± 3.79	N.S.
Open water (ha)	3.43 ± 5.43	0.80 ± 1.50	N.S.
Open water (%)	42.01 ± 36.43	39.20 ± 30.76	N.S.
Life-form diversity	1.53 ± 0.78	1.66 ± 0.49	N.S.
Surface water			
Area (ha)	8.44 ± 15.26	3.16 ± 5.07	0.05
Irregularity	2.71 ± 1.50	2.41 ± 0.88	N.S.
Perimeter (m)	2,261.48 ± 2,099.39	1,057.20 ± 803.04	0.05
Spatial relations			
Interwetland distance (m)	438.93 ± 465.55	698.10 ± 458.28	N.S.
Distance to road (m)	954.99 ± 835.16	125.00 ± 113.27	0.001
Water chemistry			
pH	6.38 ± 0.65	6.74 ± 0.42	N.S.
Conductivity	43.30 ± 52.29	64.40 ± 36.19	0.01

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

Fig. 12. Small, scrub–shrub wetlands dominated by alder–willow life-form vegetation are used especially by green-backed heron (*Butorides striatus*). *Photo by J. R. Longcore.*

the area of alder–willow swale ($r_s = 0.83$, $P < 0.05$) and negatively related to the amount of ericaceous cover ($r_s = -0.89$, $P < 0.05$). Ericaceous vegetation is associated with acidic, nutrient-poor waters not used by green-backed herons. Farm ponds and small, water-filled depressions beside roads were typical habitats where the herons were observed. These wetlands were often near abundant sources of nutrients (road-salt, animal manure, or agricultural fertilizer), a variable that may contribute to the high conductivity of waters in the wetlands used (Table 7). The herons seemed sensitive to wetland area, and, unlike all other species reviewed, frequented smaller rather than larger wetlands (Fig. 9). An observability bias may complicate conclusions about area-sensitivity, however, because green-backed herons may be more observable on smaller than larger wetlands. Green-backed herons occupied used wetlands (used ≥1 year) 40% of the total years of study. Models of habitat selection by green-backed herons are presented in Table A-6.

Osprey

The osprey occurred on 49 (56%) of the wetlands. Osprey occasionally used wetlands <1 ha, but occurred more regularly on larger wetlands (Fig. 13). They used wetlands of glacial origin (7.1 osprey per 100 h) and those created by beaver and humans (6.2 osprey per 100 h) in equal proportions ($P > 0.05$). Wetlands used by osprey contained greater wetland area, more open water, and longer shorelines than unused wetlands (Table 8). Vegetation on used wetlands was characterized by an increased availability of emergent and aquatic-bed plants (Table 8). Water pH and conductivity were lower on used than on unused wetlands (Table 8). Wetlands near other wetlands were used more frequently than were isolated wetlands (Table 8). Abundance of osprey on used wetlands was related positively to wetland area ($r_s = 0.56$, $P < 0.001$). Osprey occupied used wetlands (used ≥1 year) 57% of the total years of study.

Foraging success of osprey is strongly related to the abundance of benthic-feeding fish in wetlands (Swenson 1979). Our data suggest that osprey prefer shallow wetlands with beds of emergent and aquatic-bed vegetation that provide abundant feeding and nursery habitat for bottom-dwelling fish. They seemed to prefer wetlands with lower pH and reduced conductivity because the increase in water clarity may improve prey detectability, enhancing foraging success (Eriksson 1985). Using wetlands close to others may provide osprey with a number of alternate foraging sites within close range of nest sites. Models of habitat selection by osprey are presented in Table A-7.

Bald Eagle

The bald eagle occurred on 11 (18%) of the wetlands (habitat analysis was restricted to wetlands on the Moosehorn NWR and Beddington–Cherryfield study areas because bald eagles were not nesting in the vicinity of the Dixmont study area when we collected data). The bald eagle is a strongly

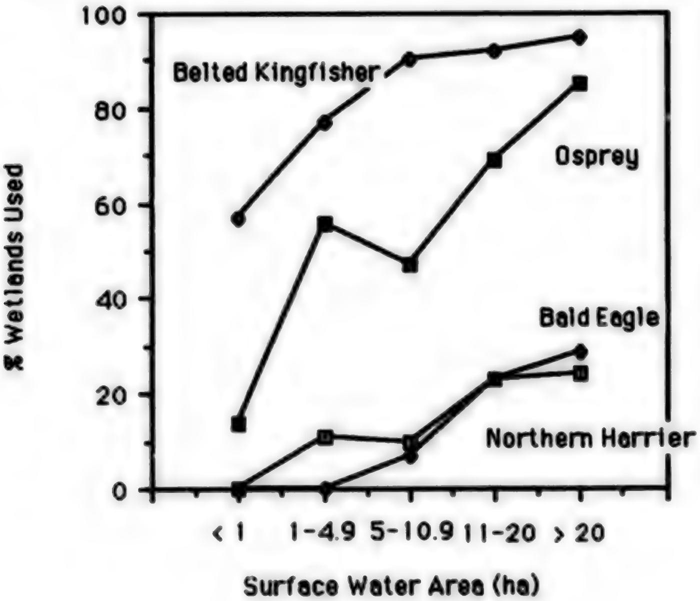

Fig. 13. Percent occurrence by wetland size for osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), northern harrier (*Circus cyaneus*), and belted kingfisher (*Ceryle alcyon*).

Table 8. *Characteristics of wetlands used and not used by osprey (*Pandion haliaetus*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 38$ $\bar{x} \pm SD$	Used $n = 49$ $\bar{x} \pm SD$	P[a]
Vegetative life-forms			
Alder (ha)	0.43 ± 1.17	0.04 ± 0.15	N.S.
Alder (%)	8.69 ± 21.11	0.56 ± 1.38	N.S.
Aquatic-bed (ha)	0.53 ± 1.69	1.49 ± 2.79	0.05
Aquatic-bed (%)	16.13 ± 23.73	24.96 ± 31.98	N.S.
Emergent (ha)	0.69 ± 0.85	2.93 ± 4.96	0.01
Emergent (%)	28.05 ± 29.25	30.12 ± 29.82	N.S.
Ericaceous (ha)	0.47 ± 1.77	1.52 ± 7.41	N.S.
Ericaceous (%)	4.77 ± 8.06	5.54 ± 13.28	N.S.
Timber (ha)	1.15 ± 5.42	0.21 ± 1.02	N.S.
Timber (%)	9.77 ± 20.63	2.94 ± 11.17	N.S.
Open water (ha)	1.26 ± 2.22	4.97 ± 6.43	0.01
Open water (%)	35.95 ± 34.49	44.85 ± 37.28	N.S.
Life-form diversity	1.48 ± 0.82	1.58 ± 0.73	N.S.
Surface water			
Area (ha)	4.48 ± 9.73	11.39 ± 17.51	0.001
Irregularity	2.58 ± 1.30	2.72 ± 1.60	N.S.
Perimeter (m)	1,454.38 ± 1,080.15	2,836.08 ± 2,432.15	0.001
Spatial relations			
Interwetland distance (m)	653.23 ± 475.67	278.46 ± 404.01	0.001
Distance to road (m)	780.38 ± 599.17	1,010.00 ± 979.49	N.S.
Water chemistry			
pH	6.52 ± 0.67	6.28 ± 0.60	0.05
Conductivity	59.10 ± 72.64	30.96 ± 10.21	0.001

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

area-sensitive species and did not use wetlands <5 ha (Fig. 13). They used wetlands of beaver or human origin that were larger, had more extensive shorelines, and had increased availability of emergent vegetation than unused wetlands (Table 9). Eagles tended to use wetlands that were close to other wetlands (Table 9).

Benthic-feeding fish predominate in the diets of inland-breeding bald eagles in North America (Haywood and Ohmart 1986). A detailed analysis of foods of Maine's inland-breeding population of bald eagles revealed that 77% of food debris at nests was composed of warm-water fish (Todd et al. 1982). Bald eagles in inland Maine primarily scavenge for food and readily eat dead and stranded fish (Palmer 1949). Shallow, warm-water wetlands with abundant emergent vegetation may support large stocks of warm-water fish vulnerable to aerial predators, so bald eagles may prefer them to the deeper, more open wetlands of inland Maine. Large wetlands and those near other wetlands might provide alternate foraging sites near nests. Although not measured in this study, nest and wetland proximity probably influences how often wetlands are visited by bald eagles. The abundance of bald eagles on used wetlands was inversely related to pH ($r_s = -0.67$, $P < 0.05$). Bald eagles occupied used wetlands (used ≥1 year) 56% of the total years of study. Models of habitat selection by bald eagles are presented in Table A-8.

Northern Harrier

The northern harrier used 12 (14%) of the study wetlands. Although wetlands <1 ha were used occasionally, harriers frequented larger wetlands (Fig. 13). Harriers used wetlands of glacial origin (1.0 harriers per 100 h) and those created by beaver or humans

Table 9. *Characteristics of wetlands used and not used by bald eagles (*Haliaeetus leucocephalus*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused n = 76 $\bar{x} \pm$ SD	Used n = 11 $\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.25 ± 0.86	0.01 ± 0.02	N.S.
Alder (%)	4.80 ± 15.59	0.09 ± 0.30	N.S.
Aquatic-bed (ha)	1.11 ± 2.48	0.71 ± 1.74	N.S.
Aquatic-bed (%)	20.11 ± 27.71	27.18 ± 36.17	N.S.
Emergent (ha)	1.36 ± 3.17	5.86 ± 5.85	0.001
Emergent (%)	26.90 ± 29.88	45.00 ± 20.72	N.S.
Ericaceous (ha)	1.02 ± 5.96	1.25 ± 2.45	N.S.
Ericaceous (%)	4.32 ± 9.37	11.27 ± 19.27	N.S.
Open water (ha)	3.32 ± 5.48	3.21 ± 4.23	N.S.
Open water (%)	43.68 ± 36.90	21.36 ± 23.11	N.S.
Timber (ha)	0.71 ± 3.97	0.06 ± 0.15	N.S.
Timber (%)	6.80 ± 17.37	0.45 ± 0.93	N.S.
Life-form diversity	1.56 ± 0.80	1.37 ± 0.43	N.S.
Surface water			
Area (ha)	7.76 ± 15.60	12.01 ± 7.80	0.01
Irregularity	2.64 ± 1.41	2.80 ± 1.87	N.S.
Perimeter (m)	2,071.76 ± 2,036.20	3,218.09 ± 1,996.24	0.01
Spatial relations			
Interwetland distance(m)	503.03 ± 480.14	55.64 ± 88.55	0.05
Distance to road (m)	951.05 ± 850.43	603.18 ± 668.07	N.S.
Water chemistry			
pH	6.39 ± 0.67	6.41 ± 0.42	N.S.
Conductivity	45.47 ± 54.15	30.50 ± 6.28	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

(0.9 harriers per 100 h) in equal proportions (P > 0.05). Wetlands used by harriers were characterized by a greater total area, area of emergent and aquatic-bed vegetation, and open water than unused (Table 10). The abundance of harriers on used wetlands was related positively to availability of emergent vegetation (r_s = 0.63, P < 0.05). Northern harriers occupied used wetlands (used ≥1 year) 50% of the total years of study.

Harriers predominantly feed on small mammals (Randall 1940) and forage by hovering, gliding, and diving over open wet meadows (Fig. 14) and marshes. Wetlands typically used by harriers for breeding have some woody vegetation for nest concealment (DeGraaf and Rudis 1983). Unlike most other large-bodied birds in this study, decreased interwetland distance was not an important feature of wetlands used by harriers (Table 10). Harriers use a variety of upland, open habitats for foraging and may not depend on having alternate wetland sites nearby for foraging. Models of habitat selection by northern harriers are presented in Table A-9.

Virginia Rail

The Virginia rail occurred on eight (9%) of the wetlands studied. Rails are highly reclusive and infrequently detected without broadcast of tape-recorded calls (Johnson and Dinsmore 1986). Our passive surveys may have underestimated occurrence and abundance. Wetlands used by rails contained a greater total area and a greater area of emergent and ericaceous vegetation compared to unused wetlands (Table 11). Combined, these two types comprise more than 8 ha of used wetlands, versus only 2.5 ha of unused wetlands.

Table 10. *Characteristics of wetlands used and not used by northern harriers (*Circus cyaneus*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 75$ $\bar{x} \pm$ SD	Used $n = 12$ $\bar{x} \pm$ SD	P^a
Vegetative life-forms			
Alder (ha)	0.25 ± 0.87	0.02 ± 0.08	N.S.
Alder (%)	4.83 ± 15.69	0.33 ± 1.15	N.S.
Aquatic-bed (ha)	0.84 ± 2.31	2.44 ± 2.58	0.01
Aquatic-bed (%)	18.56 ± 27.44	36.25 ± 33.26	N.S.
Emergent (ha)	1.40 ± 2.13	5.23 ± 8.55	0.01
Emergent (%)	29.15 ± 29.55	29.48 ± 29.79	0.05
Ericaceous (ha)	0.42 ± 1.50	5.00 ± 14.59	N.S.
Ericaceous (%)	4.60 ± 9.82	8.92 ± 17.68	N.S.
Open water (ha)	3.18 ± 5.61	4.10 ± 2.85	0.05
Open water (%)	39.96 ± 36.85	46.50 ± 32.07	N.S.
Timber (ha)	0.64 ± 3.92	0.59 ± 2.03	N.S.
Timber (%)	6.88 ± 17.47	0.50 ± 1.73	N.S.
Life-form diversity	1.50 ± 0.73	1.77 ± 0.95	N.S.
Surface water			
Area (ha)	6.67 ± 9.19	18.46 ± 32.11	0.05
Irregularity	2.64 ± 1.47	2.78 ± 1.50	N.S.
Perimeter (m)	2,015.69 ± 1,820.03	3,473.00 ± 2,959.42	0.05
Spatial relations			
Interwetland distance (m)	454.11 ± 472.02	398.67 ± 502.07	N.S.
Distance to road (m)	871.24 ± 722.64	1,131.00 ± 1,366.04	N.S.
Water chemistry			
pH	6.41 ± 0.65	6.29 ± 0.59	N.S.
Conductivity	44.86 ± 54.35	35.54 ± 16.50	N.S.

[a] *P*- values calculated by Mann–Whitney *U*-tests; N.S. = not significant.

Fig. 14. Stream-side meadow flooded in spring provides emergent life-form vegetation for nongame marsh birds and ducks. *Photo by J. R. Longcore.*

Table 11. *Characteristics of wetlands used and not used by Virginia rails (*Rallus limicola*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

	Unused	Used	
	$n = 79$	$n = 8$	
Variable	$\bar{x}$ ± SD	$\bar{x}$ ± SD	P^a
Vegetative life-forms			
Alder (ha)	0.15 ± 0.52	0.97 ± 2.26	N.S.
Alder (%)	3.50 ± 12.89	12.29 ± 28.34	N.S.
Aquatic-bed (ha)	1.05 ± 2.43	1.20 ± 2.11	N.S
Aquatic-bed (%)	20.71 ± 28.47	24.29 ± 34.22	N.S.
Emergent (ha)	1.68 ± 3.30	4.77 ± 7.87	0.05
Emergent (%)	29.80 ± 29.73	22.29 ± 26.49	N.S.
Ericaceous (ha)	0.85 ± 5.70	3.30 ± 4.43	0.01
Ericaceous (%)	4.09 ± 9.24	17.86 ± 21.61	0.05
Open water (ha)	3.33 ± 5.47	3.11 ± 3.28	N.S.
Open water (%)	42.63 ± 36.66	20.71 ± 22.29	N.S.
Timber (ha)	0.26 ± 0.92	4.84 ± 12.80	N.S.
Timber (%)	5.83 ± 16.04	8.00 ± 21.17	N.S.
Life-form diversity	1.52 ± 0.79	1.67 ± 0.48	N.S.
Surface water			
Area (ha)	7.46 ± 14.06	17.78 ± 21.36	0.05
Irregularity	2.70 ± 1.50	2.12 ± 0.91	N.S.
Perimeter (m)	2,205.63 ± 2,106.63	2,343.29 ± 1,456.01	N.S.
Spatial relations			
Interwetland distance (m)	421.29 ± 457.46	734.14 ± 595.73	N.S.
Distance to road (m)	954.50 ± 847.49	365.00 ± 385.21	N.S.
Water chemistry			
pH	6.37 ± 0.66	6.57 ± 0.34	N.S.
Conductivity	43.24 ± 52.89	47.36 ± 15.19	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

Other researchers have reported that breeding Virginia rails prefer littoral sites in a wetland dominated by robust emergents (Weller and Spatcher 1965; Zimmerman 1977; Johnson and Dinsmore 1986; Swift 1989). Likewise, migrant Virginia rails in Missouri use moist-soil impoundments associated with rank and dense cover with water depths <10 cm (Fredrickson and Reid 1986).

In Maine, clumps of ericaceous vegetation, in addition to dense emergent growth, may provide cover for adults and broods. Beds of ericaceous vegetation also overlie moist soil that rails can probe for invertebrate food, a major portion of the adult's food source. In comparison, such food composes 62% of the rail's diet in a northwestern Iowa glacial wetland (Horak 1970). The abundance of Virginia rails on used wetlands was related positively ($r_s = 0.88$, $P < 0.01$) to shoreline length. They used either human- or beaver-created wetlands.

Although wetlands used by rails had a slightly larger wetland area than the unused (Table 11), use seemed independent of wetland size (Fig. 15; see also Brown and Dinsmore 1986) but was related to area of emergent- and ericaceous-dominated nesting habitat (Table 11). Virginia rails occupied used wetlands (used ≥1 year) 48% of the total years of study. Models of habitat selection by Virginia rails are presented in Table A-10.

Sora

The sora occurred on 18 (21%) of the wetlands. Soras, like the Virginia rails, are reclusive, and our passive surveys may have underestimated occurrence and abundance. Also like the Virginia rails, soras used wetlands characterized by increased availability of emergent and ericaceous vegetation (Table 12).

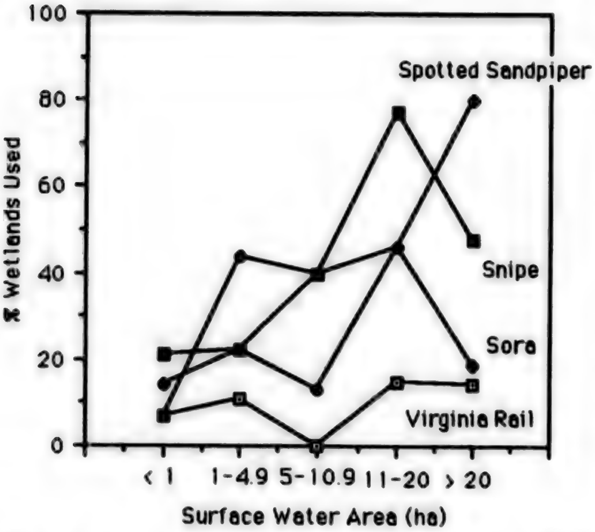

Fig. 15. Percent occurrence by wetland size for Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), spotted sandpiper (*Actitis macularia*), and common snipe (*Gallinago gallinago*).

They seemed to prefer wetlands with intermediate cover-to-water ratios—wetlands with an extensive shoreline—but a lower percentage of open water (Table 12). The abundance of soras on used wetlands was related positively to total wetland area ($r_s = 0.60$, $P < 0.01$). Soras used either beaver- or human-created wetlands that varied widely in size (Fig. 15). Similarly, Brown and Dinsmore (1986) considered the sora to be an area-independent species. Soras occupied used wetlands (used ≥1 year) 55% of the total years of study. Models of habitat selection by soras are presented in Table A-11.

Spotted Sandpiper

The spotted sandpiper occurred on 40 (46%) of the wetlands. Wetlands used by sandpipers were characterized by increased availability of aquatic-bed and emergent vegetation, increased wetland area and

Table 12. *Characteristics of wetlands used and not used by soras (*Porzana carolina*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused *n* = 69 x̄ ± SD	Used *n* = 18 x̄ ± SD	*P*[a]
Vegetative life-forms			
Alder (ha)	0.25 ± 0.90	0.10 ± 0.22	N.S.
Alder (%)	3.96 ± 13.84	5.17 ± 17.82	N.S.
Aquatic-bed (ha)	1.00 ± 2.48	1.30 ± 2.11	N.S.
Aquatic-bed (%)	19.35 ± 27.79	27.33 ± 32.29	N.S.
Emergent (ha)	1.19 ± 1.91	4.75 ± 7.12	0.01
Emergent (%)	27.01 ± 29.50	37.54 ± 28.30	N.S.
Ericaceous (ha)	0.36 ± 1.48	3.68 ± 11.93	0.05
Ericaceous (%)	3.52 ± 8.09	11.61 ± 17.80	N.S.
Timber (ha)	0.66 ± 4.09	0.51 ± 1.69	N.S.
Timber (%)	6.84 ± 17.66	2.78 ± 9.65	N.S.
Open water (ha)	3.57 ± 5.73	2.33 ± 3.19	N.S.
Open water (%)	46.35 ± 37.46	19.83 ± 19.94	0.05
Life-form diversity	1.47 ± 0.74	1.78 ± 0.84	N.S.
Surface water			
Area (ha)	6.88 ± 9.49	13.71 ± 26.84	N.S.
Irregularity	2.57 ± 1.42	3.01 ± 1.62	N.S.
Perimeter (m)	1,904.75 ± 1,536.81	3,412.50 ± 3,165.83	0.01
Spatial relations			
Interwetland distance (m)	442.64 ± 453.00	461.11 ± 560.08	N.S.
Distance to road (m)	965.17 ± 847.91	684.33 ± 761.33	N.S.
Water chemistry			
pH	6.40 ± 0.66	6.33 ± 0.58	N.S.
Conductivity	44.68 ± 56.66	39.33 ± 14.78	N.S.

[a] *P*-values calculated by Mann–Whitney *U*-tests; N.S. = not significant.

open water, decreased alder availability, decreased interwetland distance, and a more extensive shoreline development than unused wetlands (Table 13). Sandpipers used wetlands of beaver and human origin (5.2 sandpipers per 100 h) and those of glacial origin (5.2 sandpipers per 100 h) in equal proportion ($P > 0.05$).

Spotted sandpipers forage by walking along water edges and gleaning insect and other invertebrate prey. Aquatic-bed and emergent vegetation associated with sandpiper use is particularly rich in invertebrate prey in Maine freshwater wetlands (Ringelman 1980). Extensive shoreline areas may provide sandpipers many sites to search for prey. The abundance of spotted sandpipers was positively related to shoreline development on used wetlands ($r_s = 0.50$, $P < 0.05$). Sandpipers roam wetland shores when foraging and rarely defend feeding territories (Hays 1972). Availability of prey to shoreline gleaners is typically ephemeral (Davies and Houston 1981) and use of wetlands near other wetlands (Table 13) may enable sandpipers to move efficiently among alternate sites to forage.

Spotted sandpipers were moderately sensitive to wetland area. In Quebec, they were observed most frequently on large lakes with undeveloped riparian vegetation (DesGranges and Houde 1989). In Maine, however, most wetlands used by sandpipers were >1 ha, although they occasionally used smaller wetlands (Fig. 15). Spotted sandpipers occupied used wetlands (used ≥1 year) 55% of the total years of study. Models of habitat selection by spotted sandpipers are presented in Table A-12.

Table 13. *Characteristics of wetlands used and not used by spotted sandpipers* (Actitis macularia) *during the breeding season in Maine, 1977–85 (see Table 1 for complete descriptions of variables).*

	Unused	Used	
	$n = 47$	$n = 40$	
Variable	$\bar{x} \pm SD$	$\bar{x} \pm SD$	P[a]
Vegetative life-forms			
Alder (ha)	0.25 ± 0.66	0.19 ± 0.96	N.S.
Alder (%)	7.30 ± 19.42	0.57 ± 1.82	0.05
Aquatic-bed (ha)	0.43 ± 0.93	1.80 ± 3.25	0.01
Aquatic-bed (%)	15.87 ± 25.03	27.02 ± 31.88	0.05
Emergent (ha)	1.44 ± 3.44	2.50 ± 4.30	0.05
Emergent (%)	32.19 ± 32.24	25.67 ± 25.64	N.S.
Ericaceous (ha)	0.14 ± 0.39	2.12 ± 8.22	N.S.
Ericaceous (%)	2.98 ± 6.00	7.80 ± 14.86	N.S.
Timber (ha)	0.24 ± 0.64	1.09 ± 5.43	N.S.
Timber (%)	8.36 ± 20.02	3.22 ± 10.16	N.S.
Open water (ha)	1.76 ± 3.01	5.13 ± 6.73	0.01
Open water (%)	38.68 ± 36.64	43.42 ± 35.80	N.S.
Life-form diversity	1.48 ± 0.81	1.60 ± 0.71	N.S.
Surface water			
Area (ha)	4.13 ± 5.41	13.19 ± 20.20	0.001
Irregularity	2.67 ± 1.44	2.64 ± 1.51	N.S.
Perimeter (m)	1,795.51 ± 1,866.72	2,711.60 ± 2,178.03	0.01
Spatial relations			
Interwetland distance (m)	538.30 ± 472.77	338.55 ± 457.08	0.05
Distance to road (m)	809.34 ± 757.73	1021.90 ± 912.60	N.S.
Water chemistry			
pH	6.43 ± 0.61	6.34 ± 0.68	N.S.
Conductivity	42.41 ± 21.66	44.94 ± 71.74	N.S.

[a] P- values calculated by Mann–Whitney U-tests; N.S. = not significant.

Common Snipe

Common snipe occurred on 37 (42%) of the wetlands. Wetlands used by common snipe were characterized by increased availability of emergent and ericaceous vegetation, life-form diversity, and wetland area (Table 14). Cover-to-water ratios also influenced habitat use. Used wetlands contained more extensive and irregular shorelines and decreased coverage by open water than unused wetlands (Table 14). The abundance of snipe on used wetlands was related positively to availability of emergent vegetation ($r_s = 0.36$, $P < 0.05$). Snipe seemed moderately sensitive to wetland area (Fig. 15). Common snipe occupied used wetlands (used ≥1 year) 62% of the total years of study.

Although snipe use vegetated margins of lakes and rivers (Bent 1926), all wetlands used in this study were situated on beaver- or human-created impoundments. Snipe prefer habitats with moist organic soil and sparse vegetation where they can easily probe for insect larvae and earthworms that compose most of their diet (Palmer 1949; Tuck 1972). Fogarty and Arnold (1977) considered shallow, fringe areas of bogs with peaty soils the best habitats for snipe. Models of habitat selection by common snipe are presented in Table A-13.

Herring Gull

Herring gulls used 26 (30%) of the wetlands. Increased wetland area, length of shoreline, and availability of emergent vegetation were associated with herring gull use, but the gulls avoided wetlands with extensive alder swale (Table 15). Herring gulls preferred wetlands near other wetlands and those near marine environments (Table 15). They used beaver-

Table 14. *Characteristics of wetlands not used and used by common snipe* (Gallinago gallinago) *during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 50$ $\bar{x} \pm$ SD	Used $n = 37$ $\bar{x} \pm$ SD	P[a]
Vegetative life-forms			
Alder (ha)	0.16 ± 0.55	0.30 ± 1.06	N.S.
Alder (%)	6.02 ± 18.77	1.76 ± 4.71	N.S.
Aquatic-bed (ha)	1.06 ± 2.69	1.06 ± 1.97	N.S.
Aquatic-bed (%)	21.80 ± 31.35	19.92 ± 25.23	N.S.
Emergent (ha)	0.53 ± 0.73	3.82 ± 5.36	0.001
Emergent (%)	20.72 ± 28.31	40.64 ± 27.22	0.001
Ericaceous (ha)	0.08 ± 0.19	2.35 ± 8.52	0.05
Ericaceous (%)	2.94 ± 7.46	8.24 ± 14.38	0.05
Timber (ha)	0.18 ± 0.57	1.24 ± 5.64	N.S.
Timber (%)	7.10 ± 19.00	4.51 ± 12.02	N.S.
Open water (ha)	3.88 ± 6.35	2.54 ± 3.39	N.S.
Open water (%)	51.32 ± 39.56	26.73 ± 25.10	0.05
Life-form diversity	1.38 ± 0.81	1.75 ± 0.66	0.05
Surface water			
Area (ha)	5.49 ± 6.76	12.08 ± 21.00	0.01
Irregularity	2.45 ± 1.41	2.93 ± 1.52	0.05
Perimeter (m)	1,564.20 ± 1,237.34	3,098.46 ± 2,573.16	0.001
Spatial relations			
Interwetland distance (m)	497.44 ± 476.75	377.57 ± 466.94	N.S.
Distance to road (m)	889.00 ± 942.03	931.49 ± 673.83	N.S.
Water chemistry			
pH	6.30 ± 0.72	6.51 ± 0.49	N.S.
Conductivity	39.94 ± 23.25	48.49 ± 73.49	N.S.

[a] P- values calculated by Mann–Whitney U-tests; N.S. = not significant.

and human-created wetlands (81% of used wetlands) more frequently (2.9 gulls per 100 h) than wetlands of glacial origin (1.5 gulls per 100 h, $P < 0.05$). They were moderately sensitive to wetland area, indicated by most wetlands used being >20 ha (Fig. 8). Their abundance on used wetlands was related positively to the amount of emergent vegetation ($r_s = 0.52$, $P < 0.01$). Herring gulls occupied used wetlands (used ≥1 year) 51% of the total years of occupancy.

Herring gulls are omnivorous and, in freshwater habitats, forage mainly by scavenging along the shoreline of marshes and lakes (Palmer 1949). Gulls using freshwater habitats in Maine ate 77% forage fish (Mendall 1939), mainly perch (*Perca* spp.), sunfish (*Lepomis* spp.), and suckers (*Catostomus* spp.). These fish often are associated with beds of emergent vegetation like those that occurred extensively on wetlands used by herring gulls (Table 15). Large beds of emergent vegetation provide an extensive vegetation and water ecotone where gulls can forage and scavenge stranded fish (Palmer 1949).

Most herring gulls in Maine breed on small islands in coastal waters (Korschgen 1979). Gulls using wetlands in our study preferred wetlands closer to marine environments (Table 15) and may be individuals dispersed from offshore breeding colonies. Open garbage dumps may influence distribution of gulls (Hunt 1972) as wetlands near dumps in Maine often are used by gulls for loafing and roosting. Decreased inter-wetland distance (Table 15) may enable gulls to seek alternate foraging sites while minimizing their time in flight. Models of habitat selection by herring gulls are presented in Table A-14.

Table 15. *Characteristics of wetlands not used and used by herring gulls (*Larus argentatus*) during the breeding season in Maine, 1977–85 (see Table 1 for complete variable descriptions).*

Variable	Unused	Used	P[a]
	$n = 61$	$n = 26$	
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Vegetative life-forms			
Alder (ha)	0.29 ± 0.95	0.05 ± 0.19	N.S.
Alder (%)	5.87 ± 17.25	0.31 ± 0.97	0.05
Aquatic-bed (ha)	1.04 ± 2.43	1.12 ± 2.37	N.S.
Aquatic-bed (%)	20.82 ± 28.73	21.42 ± 29.39	N.S.
Emergent (ha)	1.19 ± 3.25	3.66 ± 4.68	0.001
Emergent (%)	26.11 ± 30.17	36.42 ± 26.72	N.S.
Ericaceous (ha)	1.14 ± 6.62	0.83 ± 1.91	N.S.
Ericaceous (%)	4.38 ± 9.58	7.12 ± 14.32	N.S.
Timber (ha)	0.88 ± 4.42	0.05 ± 0.15	N.S.
Timber (%)	8.15 ± 19.04	0.96 ± 3.74	N.S.
Open water (ha)	2.51 ± 4.21	5.19 ± 7.02	N.S.
Open water (%)	42.54 ± 36.80	36.92 ± 34.87	N.S.
Life-form diversity	1.56 ± 0.80	1.46 ± 0.70	N.S.
Surface water			
Area (ha)	7.07 ± 16.69	11.17 ± 8.98	0.001
Irregularity	2.65 ± 1.47	2.67 ± 1.50	N.S.
Perimeter (m)	1,984.61 ± 2,098.06	2,761.23 ± 1,879.67	0.01
Spatial relations			
Interwetland distance (m)	586.18 ± 487.75	118.65 ± 203.25	0.001
Distance to road (m)	877.48 ± 852.51	976.50 ± 802.07	N.S.
Marine distance (km)	18.65 ± 10.13	9.93 ± 7.97	0.01
Water chemistry			
pH	6.36 ± 0.71	6.46 ± 0.45	N.S.
Conductivity	48.69 ± 59.99	31.58 ± 6.90	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

Belted Kingfisher

The belted kingfisher was widely distributed and occurred on 74 (85%) of the wetlands. The kingfisher was an area-independent species and frequented wetlands of all sizes (Fig. 13). They used wetlands of glacial origin (23.4 kingfishers per 100 h) and those created by beaver or humans (15.1 kingfishers per 100 h) in equal proportion ($P > 0.05$). They avoided wetlands with extensive alder swale and preferred wetlands with increased wetland area, open water, shoreline development, and availability of aquatic-bed vegetation (Table 16). The abundance of kingfishers on used wetlands was related positively to the availability of aquatic-bed vegetation ($r_s = 0.39$, $P < 0.001$) and wetland area ($r_s = 0.34$, $P < 0.001$), and negatively to pH ($r_s = -0.35$, $P < 0.001$) and conductivity ($r_s = -0.24$, $P < 0.05$). Belted kingfishers occupied used wetlands (used ≥1 year) 75% of the total years of study.

Kingfishers feed on small fish by diving into shallow borders of water bodies. They prefer areas with aquatic-bed vegetation (Table 16) that provides cover and foraging habitat for small fish. Kingfisher probably avoided areas with extensive alder swale because tall, woody growth interferes with diving and limits access to the water surface. They evidently require water with low turbidity (Palmer 1949) and the lower pH and conductivity of water associated with increased Kingfisher abundance may be related

Table 16. *Characteristics of wetlands used and not used by belted kingfishers (*Ceryle alcyon*) during the breeding season in Maine, 1977–85 (see Table 1 for complete description of variables).*

Variable	Unused $n = 13$ $\bar{x} \pm$ SD	Used $n = 74$ $\bar{x} \pm$ SD	P[a]
Vegetative life-forms			
Alder (ha)	0.48 ± 0.99	0.17 ± 0.77	0.05
Alder (%)	12.62 ± 28.82	2.73 ± 10.07	0.05
Aquatic-bed (ha)	0.04 ± 0.08	1.24 ± 2.56	0.01
Aquatic-bed (%)	9.85 ± 17.37	22.96 ± 29.98	N.S.
Emergent (ha)	1.44 ± 3.03	2.01 ± 4.02	N.S.
Emergent (%)	41.08 ± 31.80	27.10 ± 28.69	N.S.
Ericaceous (ha)	0.53 ± 1.51	1.14 ± 6.07	N.S.
Ericaceous (%)	4.62 ± 6.71	5.30 ± 11.83	N.S.
Timber (ha)	0.01 ± 0.05	0.74 ± 4.02	N.S.
Timber (%)	0.38 ± 1.39	6.99 ± 17.57	N.S.
Open water (ha)	1.40 ± 3.54	3.65 ± 5.52	0.05
Open water (%)	31.46 ± 35.25	42.51 ± 36.26	N.S.
Life-form diversity	1.37 ± 0.71	1.56 ± 0.78	N.S.
Surface water			
Area (ha)	3.96 ± 8.17	9.05 ± 15.68	0.01
Irregularity	2.74 ± 1.63	2.64 ± 1.45	N.S.
Perimeter (m)	1,563.85 ± 1,951.51	2,331.39 ± 2,064.78	0.05
Spatial relations			
Interwetland distance (m)	561.00 ± 483.24	426.34 ± 472.37	N.S.
Distance to road (m)	710.69 ± 721.32	941.57 ± 852.35	N.S.
Water chemistry			
pH	6.64 ± 0.44	6.35 ± 0.66	N.S.
Conductivity	40.85 ± 16.12	44.05 ± 54.80	N.S.

[a] P-values calculated by Mann–Whitney U-tests; N.S. = not significant.

to their need for water clarity to locate and capture prey (Eriksson 1985). Models of habitat selection by belted kingfishers are presented in Table A-15.

Analysis of Wetland Habitats Available to Water Birds

Wetland data were reduced through principal components analysis to the major axes that accounted for most of the variation among descriptor variables. The first three axes retained ex-plained 51% of the variation in the original data set (Table 17). Axis 1, the conductivity–acidity axis, was associated with ionic content of water and pH and accounted for 21% of the variance. Axis 2, the cover-to-water interspersion axis, had a positive loading with the percent of unvegetated surface water and a negative loading with the percent of surface water in emergent vegetation and accounted for 16% of the variance. Axis 3, the size–isolation axis, had a positive loading with wetland area, a negative loading with interwetland distance and accounted for 14% of the total variance.

In relation to axes 1–3, the common loon evidently used intermediate-sized wetlands with relatively open, acidic and nutrient-poor water (Fig. 16). A large group of shallow-diving or littoral species (double-crested cormorant, pied-billed grebe, spotted sandpiper, osprey, northern harrier, belted kingfisher) used wetlands containing an intermediate mixture of emergent vegetation and open water with low to intermediate levels of pH and conductivity (Fig. 16). The herring gull and great blue heron used wetlands with intermediate pH and nutrient

Table 17. *Loadings* (r) *on habitat variables from principal component analysis of 85 wetlands in central and eastern Maine, 1977–85.*

	r		
Variable[a]	Axis 1	Axis 2	Axis 3
pH	+ 0.65		
Conductivity	+ 0.75		
Open water (%)		+0.91	
Emergent vegetation (%)		–0.78	
Wetland area			+0.75
Interwetland distance			–0.60
Cumulative % variance	21%	37%	51%

[a] Only variables with loadings (*r*) ≥ 0.60 reported.

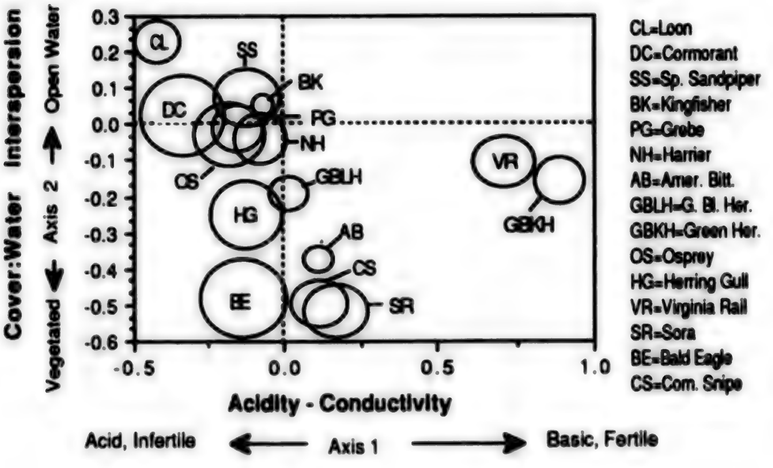

Fig. 16. Relations between species and the first three axes retained from principal component analysis. Values of Axis 1 (acidity–conductivity) are positively related to wetland pH and conductivity. Values of Axis 2 (cover-to-water interspersion) are positively related to percent open water and inversely related to percent emergent vegetation. Size of circles corresponds with Axis 3 (size–isolation), to which surface water area was positively related and interwetland distance was negatively related. Mean values of principal component scores are shown for wetlands used by each species.

ranges, as did the American bittern, common snipe, sora, and bald eagle, but the latter species favored more extensively vegetated wetlands than did the gull or heron. The bald eagle used large, nonisolated wetlands dominated by emergent vegetation. The Virginia rail and green-backed heron used wetlands that had waters of relatively high pH and conductivity (Fig. 16).

Species Responses to Wetland Acidity

Our studies that examined abundance and distribution of 15 waterbird species on wetlands with low to circumneutral values for pH (4.5–7.0) showed that three species, all piscivores (common loon, double-crested cormorant, osprey), used wetlands that were more acidic (pH <6.3) than wetlands they did not use. Despite their relative acidity, however, mean pH values for wetlands used by these species were circumneutral (pH >6.0). None of the species studied used wetlands of higher pH than unused wetlands. The abundance of three species (double-crested cormorant, bald eagle, belted kingfisher) was negatively correlated with wetland pH, implying that within the pH range of occupied wetlands more individuals of these species occurred on wetlands of lower pH. The abundance of any species and pH were not positively correlated.

Many species of aquatic birds, particularly piscivores, are attracted to wetlands of moderate acidity (DesGranges and Darveau 1985). Although fish populations may be reduced in acidified wetlands (Almer et al. 1974; Ryder et al. 1974), suspended particulate matter may precipitate from the water column at low pH, resulting in increased water transparency (Eriksson 1985). This may improve encounter rates with prey and capture success for fish-eating species that pursue their prey underwater, possibly compensating for decreased density of fish.

Our study, relying on correlations and not experimental manipulations, did not allow us to determine whether the association between wetland pH and these fish-eating species was directly related to a preference for waters of lower pH or indirectly related because of a preference for wetlands with deep, open waters that typically had lower pH than more extensively vegetated wetlands. If wetland pH is so low that fish can no longer survive, any associated increase in water transparency would obviously provide little benefit to fish-eating birds (Eriksson 1985). However, all but three wetlands in our study areas had pH >5.0 (Table B-2) and probably contained fish (Haines et al. 1986), so increased water transparency could improve capture success for fish-eating species.

Some piscivorous species (double-crested cormorant, osprey, bald eagle) used large wetlands with well-developed littoral vegetation. These wetland characteristics were correlated with fish abundance and species richness in 22 Maine lakes (Haines et al. 1986). Other waterbird species (Virginia rail, sora, common snipe, great blue and green-backed herons, American bittern) were mainly associated with extensively vegetated wetlands, predominantly emergent vegetation, that generally are buffered (Moss 1980) and thus protect marsh-associated water birds from substantial negative effects associated with acidic deposition (also see DesGranges and Houde 1989). Species richness of breeding bird communities at lakes in southern Sweden was positively correlated with wetland pH (Nilsson and Nilsson 1978), but such a relation was not evident between species richness of nongame water birds and pH at wetlands in our study areas ($r^2 = -0.053$, $P > 0.05$).

Evaluation of changes in bird use and characteristics of our study wetlands, including pH, would be useful for assessing long-term effects of acid precipitation on nongame water birds in central and eastern Maine. Such changes could be assessed from baseline data included in Tables B-1 to B-4.

Ratios of Open Water-to-Cover and Waterbird Communities

Water-to-cover ratios strongly influenced avian diversity in Iowa prairie marshes (Weller and Spatcher 1965), and species richness was greatest on hemimarshes where emergent vegetation and water were highly interspersed (50% water to 50% cover). In Manitoba, the greatest densities of dabbling duck pairs were similarly associated with an intermediate ratio of emergent vegetation to water in a large marsh (Murkin et al. 1982). In our study, the extent of emergent vegetation versus open water was identified as an important feature of wetland habitats (Table 17) and possibly influenced the structure of waterbird communities.

Among the 87 wetlands that we evaluated, those with an intermediate level of emergent cover (33–66%) were used by a greater number ($P < 0.05$) of species (Kruskall–Wallis Test, $\chi^2 = 6.67$, df = 2, $P < 0.05$) than wetlands with either more (>66%) or less

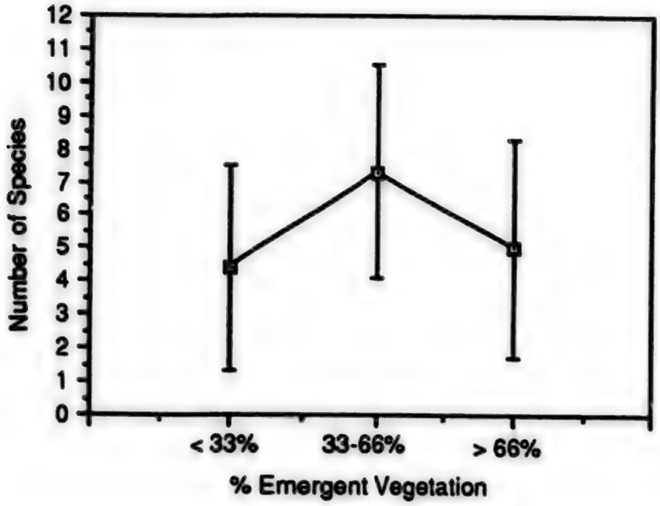

Fig. 17. Relation between water bird species richness ($\bar{x} \pm$ SD) and percent coverage by emergent vegetation on wetlands in eastern and central Maine, 1977–85. Differences between emergent cover classes are significant ($P<0.05$).

(<33%) emergent cover (Fig. 17). Emergent, aquatic plant communities may have the highest production rates of all the world's vegetation types (Moss 1980), and emergent herbaceous vegetation in Maine has dense invertebrate populations (Reinecke 1977; Ringelman 1980). All birds included in our evaluation fed on invertebrates or fish and, except for the common loon and belted kingfisher, were attracted to habitats with extensive emergent growth.

Interspersion of water and emergent vegetation and the availability of emergent vegetation were equally important in determining occurrence of individual species (Fig. 18). Marshes with dense emergent cover and minimal open water were favored by American bitterns, soras, Virginia rails, and common snipe. Predominantly open wetlands with little emergent vegetation typically supported a different assemblage, including common loons, double-crested cormorants, osprey, and belted kingfishers. Wetlands intermediately covered by emergent vegetation well interspersed with water supported pied-billed grebes, herring gulls, great blue herons, spotted sandpipers, northern harriers, bald eagles, and, occasionally, species usually preferring either more closed or open habitats. These mixed wetlands, therefore, supported more species of water birds, on the average, than either the closed or open wetlands (Fig. 18).

Effects of Wetland Size, Isolation, and Habitat Diversity on Waterbird Communities

Wetland size and isolation substantially affected species richness of birds on prairie marshes in Iowa (Brown and Dinsmore 1986). Small wetlands supported fewer species than large wetlands, and isolated wetlands supported fewer species than wetlands in complexes (Brown and Dinsmore 1986). Bird species richness increased strongly with bog area in Sweden (Bostrom and Nilsson 1983), and aquatic birds shunned smaller lakes (<15 ha) in Quebec (DesGranges and Houde 1989).

Wetlands in Maine represent distinct habitat islands of varying size and isolation that exist in a matrix of predominantly forested, upland areas. In our study, species richness of the waterbird community increased with wetland area (Fig. 19; species richness = 1.69 + 4.78 log area), decreased with wetland isolation (Fig. 20; species richness = 7.51 – 1.10 log interwetland distance), and was not related to habitat diversity within a wetland. A model that included only wetland area and isolation accounted for 43% of the total variation in species richness (adj. $r^2 = 0.43$, species richness = 3.64 + 4.49 log area – 0.83 log interwetland distance). Wetland area and isolation contributed independently to species richness because these variables were not correlated with one another (adj. $r^2 = 0.01$, $P > 0.05$). Over the range of observed values (area 0.02–117.12 ha, isolation 0–1712 m), however, wetland area contributed substantially more (37%) to variation in species richness than did wetland isolation (6%).

Wetland area and vegetative life-form diversity were not correlated (adj. $r^2 = 0.07$, $P < 0.05$), even when lacustrine systems (dominated by open water) were excluded from the comparison (adj. $r^2 = 0.09$, $P < 0.01$). The number of vegetative life-forms present, another measure of wetland habitat diversity, was not related to wetland area (adj. $r^2 = 0.10$, $P < 0.05$) and unrelated to species richness (adj. $r^2 = 0.03$, $P > 0.05$). Many larger wetlands were domi-

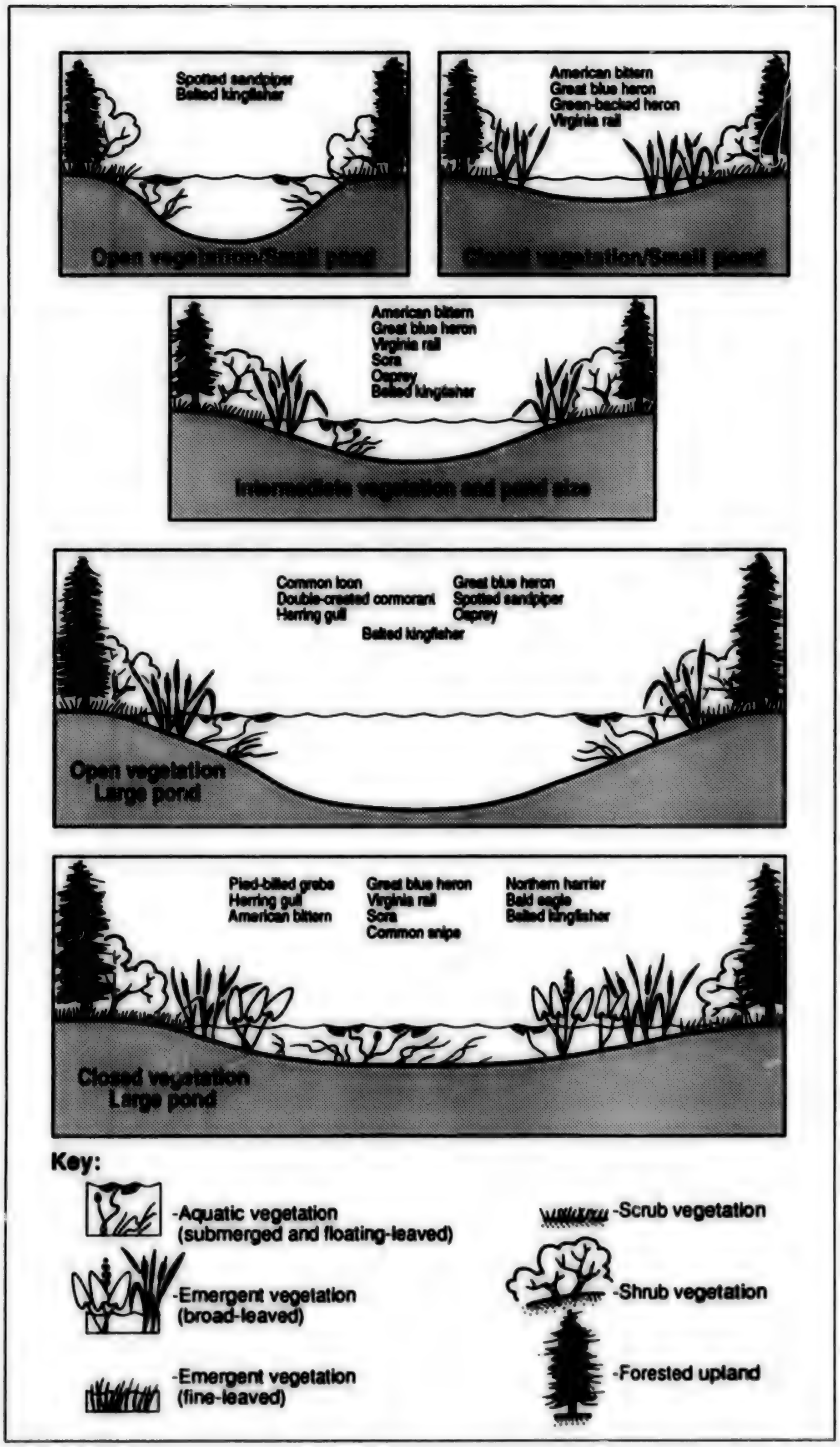

Fig. 18. Wetland habitats by prominent features (vegetation and pond size) showing the major vegetation types and the nongame water birds associated with each.

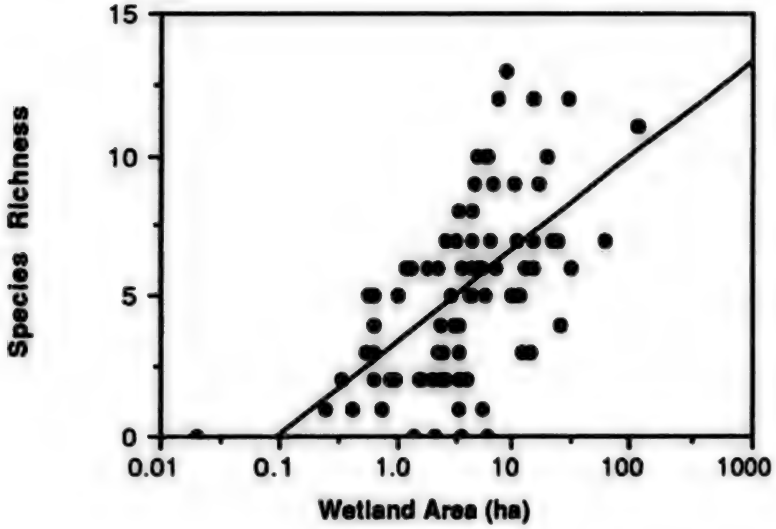

Fig. 19. Relation between species richness of nongame waterbird communities and area of 87 wetlands during the breeding season in Maine, 1977–85.

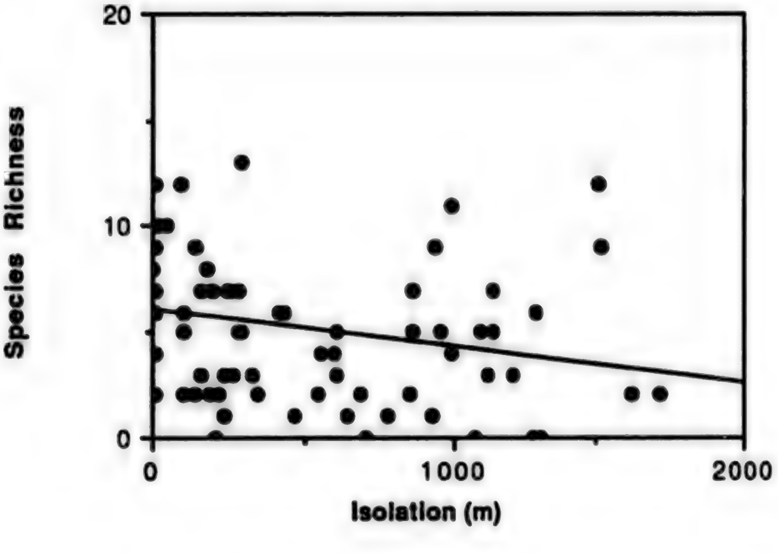

Fig. 20. Relation between species richness of nongame waterbird communities and isolation of 87 wetlands during the breeding season in Maine, 1977–85.

nated by a single vegetative life-form (e.g., sedge meadows and bogs). Therefore, habitat diversity was not substantially greater on larger than smaller wetlands in our study areas (cf. Weller and Fredrickson 1974; Kantrud and Stewart 1984) and could not account for the elevated species richness of larger wetlands.

Factors other than wetland area and isolation probably affect species richness. Of the 10 largest wetlands, only 4 were included among the 10 most species-rich sites (see also Brown and Dinsmore 1986). Additional sources of variation in species richness likely include cover-to-water ratios (Weller and Spatcher 1965), water depth (Brown and Dinsmore 1986), water chemistry (Nilsson and Nilsson 1978), water permanence (Kantrud and Stewart 1984), and rates of secondary production.

The relative contribution of area versus isolation to species richness varied with wetland size. Among the 43 smallest wetlands studied (0.02–3.66 ha), species richness was essentially unrelated to wetland area (adj. $r^2 = 0.06$, $P > 0.05$), but slightly more related to wetland isolation (adj. $r^2 = 0.16$, $P < 0.01$). Conversely, among the 44 largest wetlands studied (3.96–117.12 ha), species richness was positively related to wetland area (adj. $r^2 = 0.09$, $P < 0.05$) but unrelated to wetland isolation (adj. $r^2 = 0.02$, $P > 0.05$). A study of 30 Iowa wetlands of similar size (Brown and Dinsmore 1986), however, found that area was an important determinant of species richness at small wetlands (<5.5 ha) but not at larger wetlands.

The effects of wetland area and isolation on species diversity may be caused by occurrence of many area- and isolation-sensitive birds in the species assemblage studied (see also Brown and Dinsmore 1986). Evidently many species required large wetland areas (e.g., pied-billed grebe, common loon, double-crested cormorant, and bald eagle), whereas some species preferred wetlands near other wetlands (e.g., great blue heron, osprey, and spotted sandpiper, as well as the bald eagle). Piscivorous species were particularly sensitive to wetland area (Figs. 8 and 13). Numbers of these aquatic species were more strongly related to wetland area ($r_s = 0.67$, $P < 0.05$) than numbers of semiaquatic species ($r_s = 0.43$, $P < 0.05$), perhaps because the open water sought out by diving birds was more abundant at larger wetlands ($r_s = 0.69$, $P < 0.05$). Wetland area is also a predictor of fish abundance and diversity on small lakes (<50 ha) in Maine (Haines et al. 1986). Small wetlands may not provide a sufficient quantity of habitat or prey for many large-bodied species, and shorter interwetland distance may provide certain species with alternate foraging sites while minimizing their time in flight. Therefore, smaller, more isolated wetlands tend to be used by fewer species of waterbirds (Figs. 19 and 20).

Patterns of Annual Variation in Wetland Occupancy, Geographic Distribution, and Relative Abundance

Annual variation in habitat use, as measured by the proportion of years a given species occupied wetlands used more than once during our study, ranged from 0.40 (green-backed heron) to 0.75 (belted kingfisher). Among the 15 species examined, two correlates of annual variation in wetland use identified were relative abundance (i.e., sighting frequency on used wetlands, $r^2 = 0.62$, $P < 0.05$) and extent of distribution (i.e., proportion of all wetlands studied used by a given species, $r^2 = 0.71$, $P < 0.05$). Thus, wetland use by well-distributed species occurring at relatively high densities was more predictable than wetland use by less abundant species of restricted distribution. Among the 15 species studied, relative abundance showed some association ($r^2 = 0.37$, $P < 0.05$) with the extent of distribution (Fig. 21). Exceptions to this trend included the pied-billed grebe and double-crested cormorant (also sora and Virginia rail, whose numbers likely were underestimated), of restricted distribution but occurring abundantly at used sites (Fig. 21, Quadrant IV). Three species displayed low density and restricted distribution (green-backed heron, northern harrier, and bald eagle; Fig. 21, Quadrant III), and two species were of widespread distribution and elevated abundance (great blue heron and belted kingfisher; Fig. 21, Quadrant I), but none, except perhaps the

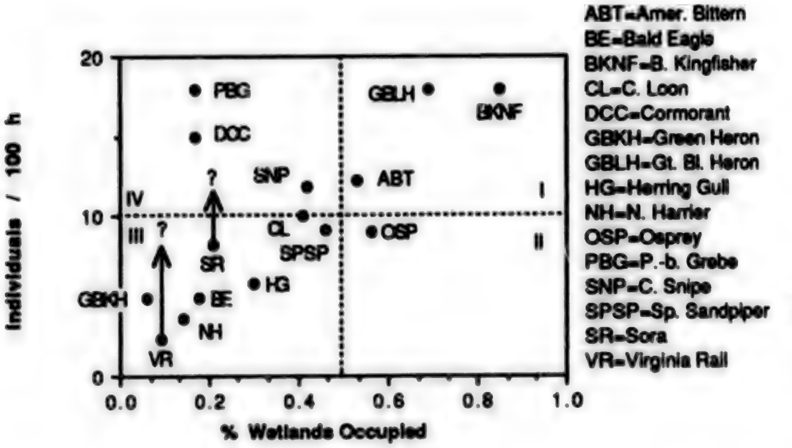

Fig. 21. Relation between relative abundance and extent of distribution of 15 species of nongame water birds studied during the breeding season in Maine, 1977–85.

Table 18. *Habitat differences among wetlands in three study areas in central and eastern Maine, 1977–85.*

	Study areas			
	Dixmont ($n = 26$)	Moosehorn NWR ($n = 32$)	Beddington–Cherryfield ($n = 29$)	
Variable	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	$\bar{x} \pm$ SD	*P*[a]
OPEN(%)	36.0 ± 27.9	31.2 ± 30.3	55.8 ± 43.9	0.05
AQUAT(%)	15.8 ± 20.6	12.1 ± 19.6	35.3 ± 37.5	0.01
AQUAT(HA)	0.7 ± 1.6	0.4 ± 0.9	2.1 ± 3.5	0.05
EMERG(%)	21.2 ± 22.0	48.0 ± 27.9	15.4 ± 26.3	0.001
EMERG(HA)	0.7 ± 0.9	3.2 ± 4.2	1.5 ± 4.6	0.05
IWDIST	895.8 ± 408.4	202.5 ± 308.3	312.7 ± 400.9	0.001
RDDIST	590.9 ± 371.2	922.3 ± 692.3	1173.6 ± 1147.9	0.05
PH	6.9 ± 0.2	6.6 ± 0.3	5.7 ± 0.6	0.001
COND	76.2 ± 84.5	33.2 ± 6.9	25.7 ± 8.9	0.01

[a] *P*- values according to Kruskal–Wallis test.

osprey, was of widespread distribution and low abundance (Fig. 21, Quadrant II).

Regional Variation in Wetland Habitats and Waterbird Use

Wetlands in the three study areas differed ($P < 0.05$) in nine wetland characteristics (Table 18), and variation in wetland habitats was associated with differences in topography, soils, and management efforts among study areas. The Dixmont area had rolling topography, relatively fertile soils, and high acid-neutralizing capacity. Wetlands there were relatively isolated from other wetlands, near roads, typically beaver-created, and had high pH and conductivity (Table 18). Piscivorous birds (common loon, double-crested cormorant, osprey, belted kingfisher) were observed less frequently in the Dixmont area (Table 19), perhaps because these species generally preferred less isolated wetlands with more open and lower pH waters than were available. The Dixmont area was farther from marine and major

Table 19. *Sighting frequency of water birds on wetlands in three study areas in central and eastern Maine, 1977–85.*

	Individuals per 100 h observation		
Species	Dixmont	Moosehorn	Beddington–Cherryfield
Pied-billed grebe	8.1	2.7	8.7
Common loon	0.4	2.7	10.5
Herring gull	0.0	5.7	1.7
Double-crested cormorant	0.0	1.3	10.6
American bittern	14.5	5.9	6.0
Great blue heron	5.2	24.1	12.1
Green-backed heron	0.6	0.2	0.0
Virginia rail	1.2	0.3	0.3
Sora	1.7	3.0	3.8
Common snipe	5.9	9.9	5.8
Spotted sandpiper	2.3	7.5	5.0
Northern harrier	0.4	0.7	1.4
Bald eagle	0.0	3.0	1.1
Osprey	0.8	9.6	6.8
Belted kingfisher	12.7	12.2	22.0

riverine environments. This distance may explain the low sighting frequency of the double-crested cormorant, herring gull, and bald eagle at the Dixmont versus the Beddington–Cherryfield and Moosehorn NWR study areas (Table 19). Populations of these species in Maine are associated mostly with the sea coast and large rivers.

The contrast between the Moosehorn NWR and Beddington–Cherryfield study areas illustrates the effect that intensive management can have on wetland characteristics and waterbird communities. The Beddington–Cherryfield and Moosehorn NWR study areas had similar topography and soils but their wetlands differed substantially (Table 18). Many wetlands in the Beddington–Cherryfield area were of glacial origin, and were characterized by extensive open water and aquatic-bed vegetation, minimal emergent growth, and relatively acidic and nutrient-poor waters. The fish-eating common loons, double-crested cormorants, and belted kingfishers were observed most frequently in the Beddington–Cherryfield area (Table 19).

The Moosehorn NWR contained mostly human-created impoundments in complexes that were periodically flooded and drained, and all dikes were limed and fertilized. Such management activities have created extensively vegetated wetlands dominated by emergent growth, with wetland waters intermediate to high in pH and conductivity (Table 18). Herring gulls, great blue herons, common snipe, spotted sandpipers, bald eagles, and osprey were seen most frequently in the Moosehorn NWR study area (Table 19).

Table 20. *Sighting frequency of water birds and probability of visit at wetland of types classified by criteria of Cowardin et al. (1979): LACUST = lacustrine, PAB = palustrine, aquatic-bed, PEWNOP and PEWPER = palustrine, emergent, nonpersistent and persistent, PFW = palustrine, forested, PSSBLD and PSSBLE = palustrine, scrub–shrub, broad-leaved-deciduous and broad-leaved-evergreen, and PUB = palustrine, unconsolidated bottom.*

	Wetland type							
Variable	LACUST	PAB	PEWNOP	PEWPER	PFW	PSSBLD	PSSBLE	PUB
n	10	8	19	13	8	6	19	3
Effort (h)	286	312	757	449	356	165	1,122	79
Visits	165	170	305	196	143	56	404	43

	Individuals per 100-h observation (probability of use/visit [%])							
Species	LACUST	PAB	PEWNOP	PWEPER	PFW	PSSBLD	PSSBLE	PUB
Pied-billed grebe	0 (0)	9.9 (14)	0.3 (1)	2.4 (6)	5.1 (8)	0.6 (2)	15.0 (21)	0 (0)
Common loon	37.1 (47)	7.7 (11)	2.1 (5)	1.6 (4)	2.2 (5)	0.6 (2)	2.7 (6)	0 (0)
Herring gull	3.1 (4)	2.6 (4)	5.9 (9)	3.6 (6)	0 (0)	3.0 (7)	1.1 (2)	0 (0)
Double-crested cormorant	5.3 (6)	2.6 (3)	1.8 (3)	0.4 (1)	0 (0)	0 (0)	11.9 (12)	0 (0)
American bittern	0.4 (1)	7.0 (12)	5.1 (11)	12.2 (22)	7.8 (17)	3.6 (11)	11.9 (22)	0 (0)
Great blue heron	7.7 (12)	21.8 (25)	24.6 (33)	12.9 (22)	4.8 (11)	12.1 (27)	12.7 (21)	0 (0)
Green-backed heron	0 (0)	0 (0)	0 (0)	0.9 (1)	0 (0)	3.0 (7)	0.1 (0)	0 (0)
Virginia rail	0 (0)	0 (0)	0.3 (1)	0.4 (1)	2.0 (5)	1.8 (4)	0.5 (2)	0 (0)
Sora	0 (0)	0.6 (1)	3.8 (8)	2.4 (5)	2.5 (5)	4.8 (13)	4.4 (8)	0 (0)
Common snipe	0 (0)	3.2 (5)	13.1 (23)	7.8 (15)	3.9 (8)	3.6 (9)	8.2 (10)	0 (0)
Spotted sandpiper	7.7 (9)	5.8 (9)	7.1 (11)	5.6 (11)	2.5 (6)	3.0 (11)	4.4 (10)	2.5 (2)
Northern harrier	0 (0)	1.0 (2)	0.9 (2)	0.4 (1)	0 (0)	1.2 (2)	1.8 (4)	0 (0)
Bald eagle	0 (0)	0.6 (1)	4.3 (9)	1.6 (3)	0 (0)	1.2 (4)	0.9 (2)	0 (0)
Osprey	11.5 (15)	9.2 (13)	10.6 (19)	5.3 (10)	0.6 (1)	0.6 (2)	4.8 (10)	1.3 (2)
Belted kingfisher	28.4 (38)	18.9 (29)	11.3 (23)	12.9 (27)	19.6 (40)	8.5 (21)	18.4 (39)	7.6 (14)
Species richness	8	13	14	15	10	14	15	3

Bird Use of Wetland Types

The highest estimates of species diversity occurred among palustrine emergent, scrub–shrub, and aquatic-bed wetlands (Table 20). Lacustrine systems, most of which were in the Beddington–Cherryfield area, were used by a distinct community of water birds, including loons, herring gulls, cormorants, great blue herons, spotted sandpipers, osprey, and kingfishers. Palustrine forested wetlands were intermediate in degree of community overlap between lacustrine and palustrine scrub–shrub, emergent, and aquatic-bed wetlands. Palustrine unconsolidated-bottom wetlands were characterized by a poorly developed shoreline, sparse vegetative growth in the littoral, and a reduced wetland area. Wetlands of this type were frequented only by belted kingfishers, spotted sandpipers, and osprey.

Species use of wetlands, typed according to the state of Maine system (McCall 1972), is presented in Table 21. Inland, open, freshwater wetlands contained an abundance of only a few species (common loon, great blue heron, spotted sandpiper, osprey, and belted kingfisher). Inland, deep, freshwater marshes and bogs supported the richest waterbird communities. Pied-billed grebes and American bitterns used bogs more often than marshes, whereas great blue herons were seen most often at marshes. Green-backed herons were seen mostly at shrub swamps. Species richness of waterbird com-

Table 21. *Sighting frequency of water birds and probability of visit at wetland of types classified by criteria of McCall (1972) for the Maine Wetlands Inventory.*

	Wetland type				
Variable	Bog	Wooded swamp	Open freshwater	Deep, fresh marsh	Shrub swamp
n	16	9	15	43	4
Effort (h)	929	427	425	1632	114
Visits	311	165	263	730	32

	Individuals per 100-h observation (probability of use/visit [%])				
Species	Bog	Wooded swamp	Open freshwater	Deep, fresh marsh	Shrub swamp
Pied-billed grebe	17.8 (27)	4.7 (8)	0 (0)	2.7 (5)	0 (0)
Common loon	1.5 (5)	1.9 (4)	27.1 (32)	3.4 (6)	0 (0)
Herring gull	0.4 (1)	0 (0)	2.1 (3)	4.8 (7)	3.5 (9)
Double-crested Cormorant	14.3 (15)	0 (0)	3.8 (5)	1.5 (2)	0 (0)
American bittern	12.7 (24)	9.8 (22)	0.5 (1)	7.4 (14)	1.7 (6)
Great blue heron	10.8 (21)	4.2 (10)	5.6 (8)	22.0 (29)	9.7 (28)
Green-backed heron	0 (0)	0 (0)	0 (0)	0.3 (1)	4.4 (13)
Virginia rail	0.6 (2)	1.6 (4)	0 (0)	0.2 (1)	2.6 (6)
Sora	5.3 (10)	2.1 (4)	0 (0)	2.6 (5)	7.0 (22)
Common snipe	9.8 (13)	3.5 (7)	0 (0)	8.8 (15)	4.4 (12)
Spotted sandpiper	4.4 (11)	2.1 (6)	6.3 (7)	6.5 (11)	0.9 (3)
Northern harrier	1.6 (5)	0 (0)	1.2 (2)	0.7 (1)	1.8 (3)
Bald eagle	0.9 (2)	0 (0)	0 (0)	2.7 (5)	1.7 (6)
Osprey	4.6 (10)	0.5 (1)	8.7 (11)	8.6 (14)	0.9 (3)
Belted kingfisher	17.5 (14)	18.3 (39)	24.0 (31)	14.1 (26)	7.0 (22)
Species richness	14	10	9	15	12

Table 22. *Habitat differences among wetlands of glacial origin and those created by beavers* (Castor canadensis) *or humans in central and eastern Maine, 1977–85 (see Table 1 for complete description of variables).*

	Glacial (n = 20)	Beaver–human (n = 67)	
Variable	$\bar{x}$ ± SD	$\bar{x}$ ± SD	P[a]
OPEN(%)	80.3 ± 28.3	29.1 ± 29.3	0.0001
EMERG(%)	8.6 ± 21.0	35.3 ± 28.9	0.0001
TIMB(%)	0.0 ± 0.0	17.8 ± 18.3	–
ALDR(%)	0.0 ± 0.0	5.5 ± 16.5	–
PH	5.8 ± 0.7	6.5 ± 0.5	0.001
COND[b]	26.8 ± 10.0	48.6 ± 56.8	0.001

[a] P- values according to Kruskal–Wallis test.
[b] Conductivity.

munities at shrub and wooded swamps was intermediate between lakes and more diverse communities at marshes and bogs.

Wetlands formed by beaver- or human-created impoundments and wetlands of glacial origin had different characteristics (Table 22). In comparison to beaver- and human-created wetlands, glacial wetlands had no alder or flooded timber, less emergent vegetative cover, more coverage by open water, more regular shorelines, and waters of lower pH and ionic content. Species observed disproportionately ($P < 0.05$) at beaver- or human-created wetlands typically were associated with extensive beds of emergent vegetation, and included the pied-billed grebe, American bittern, great blue heron, green-backed heron, Virginia rail, sora, common snipe, bald eagle, and herring gull. Species using wetland types in equal proportion ($P > 0.05$) generally were shallow-water foragers or shoreline gleaners, and included the double-crested cormorant, spotted sandpiper, northern harrier, osprey, and belted kingfisher. The common loon was the only species observed disproportionately ($P < 0.05$) at wetlands of glacial origin.

Management Considerations

Our information may assist managers who need to determine values of wetland habitats in order to maintain avian diversity and protect communities of wetland birds. Our studies indicate that major differences exist in habitat use by various species of nongame water birds in Maine, although considerable overlap occurs in types of wetlands used. Wetlands that contain vegetation well interspersed with water will support many, but not all, nongame water birds on Maine wetlands because some species need deep, primarily unvegetated wetlands, whereas others prefer densely vegetated wetlands with minimal open water. In inland Maine, where scrub–shrub habitats often dominate wetlands, most nongame water birds respond positively when emergent and aquatic-bed vegetation is available, likely because of the relatively high rates of secondary (invertebrate and vertebrate) production associated with these vegetation types.

Management activities that promote growth of emergent and aquatic-bed vegetation will benefit many types of nongame water birds (grebes, bitterns, herons, rails, snipe, and northern harriers). Special habitat needs of individual species should be considered when managing wetlands; green-backed herons require extensive woody growth and pied-billed grebes prefer aquatic-bed vegetation on large wetlands. Species of restricted range and relatively low abundance (Fig. 13, Quadrant III) may deserve particular attention from managers (Rabinowitz et al. 1986). Wetland area and isolation are important considerations to managers because many water birds use only large wetlands and some prefer to use wetlands near other wetlands. Maintaining complexes of wetlands of variable sizes and cover-to-water ratios would benefit the large assemblage of water birds with area- or isolation requirements while simultaneously supporting other species that have more general requirements.

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Appendix A. Parameter Estimates for Logistic Regression Models

Models predicted wetland use by nongame water birds during the breeding season in central and eastern Maine, 1977–85 (see Table 1 for meaning of variable mnemonics). Full models include both habitat and water chemistry variables, habitat models include only habitat variables, and reduced models include only variables identified by step-wise procedure (see text). PH (pH) and COND (conductivity) are water chemistry variables. Correct classification rates (CCR's) are presented for each model.

Table A-1. *Common loon* (Gavia immer).[a]

	Full		Habitat		Reduced	
Parameter	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***
INTERCEPT	−1.45	0.66	−0.93	0.44	1.10	0.18
ALDR(HA)	−2.44	0.33	−3.04	0.18		
AQUAT(HA)	0.34	0.16	0.36	0.15		
ERIC(%)	−0.018	0.56	−0.010	0.72		
EMERG(%)	−0.0030	0.82	−0.0031	0.80		
TIMB(%)	0.021	0.30	0.018	0.32		
OPEN(HA)	0.35	0.014	0.39	0.0054	0.33	0.0033
IWDIST	−0.00018	0.82	−0.00073	0.32		
LFDINDX	0.20	0.66	0.035	0.94		
RDDIST	0.00014	0.77	0.00046	0.28		
SWIINDX	−0.13	0.59	−0.23	0.33		
PH	0.31	0.63				
COND	−0.05	0.15			−0.064	0.0055
Likelihood ratio		0.64		0.63		0.58
CCR[b] unused (%)	86		84		84	
CCR used (%)	81		80		69	
CCR overall (%)	84		82		78	

[a] *P*- values from models >0.41 predicted wetland use.

[b] Correct classification rate.

Table A-2. *Pied-billed grebe* (Podilymbus podiceps).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−11.83	0.089	−4.04	0.0056	−2.71	0.0001
ALDR(HA)	0.46	0.44	0.41	0.49		
AQUAT(HA)	0.41	0.033	0.32	0.063	0.31	0.026
ERIC(%)	0.042	0.17	0.034	0.24		
EMERG(HA)	0.17	0.25	0.13	0.37		
TIMB(%)	0.0092	0.80	−0.0029	0.93		
OPEN(%)	0.00033	0.98	−0.0032	0.83		
IWDIST	0.00036	0.69	0.00026	0.76		
LFDINDX	0.16	0.75	0.17	0.70		
RDDIST	0.00024	0.63	0.00024	0.59		
AREA	0.0029	0.97	0.029	0.67	0.072	0.026
SWIINDX	0.21	0.39	0.21	0.36		
PH	1.26	0.24				
COND	−0.017	0.61				
Likelihood ratio		0.95		0.95		0.96
CCR[b] unused (%)	82		82		82	
CCR used (%)	60		53		60	
CCR overall (%)	78		77		78	

[a] *P*-values from models >0.17 predicted wetland use.

[b] Correct classification rate.

Table A-3. *Double-crested cormorant* (Phalacrocorax auritis).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	0.32	0.96	−4.97	0.0072	−3.31	0.0001
ALDR(HA)	−9.44	0.15	−9.46	0.13		
AQUAT(%)	0.014	0.42	0.016	0.36	0.025	0.015
ERIC(%)	0.0010	0.97	0.0077	0.82		
EMERG(HA)	0.18	0.46	0.19	0.43	0.19	0.13
OPEN(%)	−0.018	0.38	−0.016	0.44		
AREA	0.23	0.0056	0.23	0.0069	0.07	0.05
IWDIST	−0.00019	0.88	−0.00024	0.82		
LFDINDX	0.25	0.70	0.10	0.87		
RDDIST	−0.000022	0.97	0.000020	0.97		
SWIINDX	0.31	0.26	0.28	0.29		
MARINE	0.013	0.81	0.033	0.48		
PH	−0.77	0.43				
COND	−0.0063	0.89				
Likelihood ratio		0.10		0.10		0.97
CCR[b] unused (%)	83		85		81	
CCR used (%)	80		87		73	
CCR overall (%)	83		85		79	

[a] *P*-values from models >0.17 predicted use.

[b] Correct classification rate.

Table A-4. *American bittern* (Botaurus lentiginosus).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−11.75	0.013	−3.56	0.0023	−10.52	0.0038
TIMB(HA)	0.82	0.13	0.67	0.19		
AQUAT(%)	0.037	0.0069	0.029	0.019	0.034	0.00090
ERIC(%)	0.031	0.27	0.017	0.51		
EMERG(HA)	0.41	0.043	0.39	0.052	0.14	0.12
OPEN(%)	−0.0034	0.79	−0.0091	0.41		
AREA	−0.13	0.050	−0.13	0.057		
IWDIST	0.00087	0.20	0.0012	0.068		
LFDINDX	1.02	0.018	1.085	0.0089	1.02	0.016
RDDIST	0.00029	0.49	0.00023	0.56		
SWIINDX	0.28	0.19	0.36	0.08	1.26	0.018
PH	1.23	0.067				
COND	0.0025	0.71				
Likelihood ratio		0.32		0.25		0.24
CCR[b] unused (%)	66		66		95	
CCR used (%)	80		80		11	
CCR overall (%)	73		73		51	

[a] *P*- values from models >0.53 predicted use.

[b] Correct classification rate.

Table A-5. *Great blue heron* (Ardea herodias).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	1.83	0.57	0.62	0.56	0.0043	0.99
TIMB(HA)	−0.13	0.44	−0.097	0.55		
AQUAT(HA)	0.32	0.30	0.34	0.23		
ERIC(%)	0.069	0.21	0.059	0.25		
EMERG(HA)	0.80	0.044	0.75	0.052	0.87	0.0069
OPEN(%)	−0.013	0.19	−0.012	0.21		
AREA	0.089	0.22	0.073	0.29		
IWDIST	−0.00058	0.38	−0.00055	0.37		
LFDINDX	−0.58	0.22	−0.49	0.27		
RDDIST	−0.00063	0.13	−0.00074	0.085		
SWIINDX	0.34	0.16	0.34	0.13		
PH	−0.24	0.66				
COND	0.0071	0.36				
Likelihood ratio		0.41		0.43		0.50
CCR[b] unused (%)	82		82		78	
CCR used (%)	73		72		57	
CCR overall (%)	76		74		63	

[a] *P*- values from models >0.69 predicted use.

[b] Correct classification rate.

Table A-6. *Green-backed heron(*Butorides striatus*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−18.28	0.16	−1.15	0.56	−22.35	0.033
ALDR(HA)	−2.39	0.18	−2.24	0.17		
AQUAT(HA)	−0.51	0.44	−0.79	0.29		
ERIC(%)	0.071	0.11	0.06	0.15	0.065	0.075
EMERG(HA)	−0.21	0.62	−0.14	0.67		
OPEN(%)	−0.018	0.48	−0.0073	0.68		
AREA	0.027	0.88	0.0058	0.97		
IWDIST	0.0014	0.35	0.0025	0.051		
LFDINDX	0.089	0.93	0.90	0.23		
RDDIST	−0.0096	0.029	−0.0075	0.025	−0.0076	0.011
SWIINDX	−0.54	0.25	−0.43	0.36		
PH	3.02	0.16			3.30	0.034
COND	−0.00032	0.96				
Likelihood ratio		0.99		0.99		0.99
CCR[b] unused (%)	82		80		75	
CCR used (%)	100		100		80	
CCR overall (%)	82		79		72	

[a] *P*-values from models >0.06 predicted use.

[b] Correct classification rate.

Table A-7. *Osprey (*Pandion haliaetus*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−18.28	0.16	−1.15	0.56	−22.35	0.033
INTERCEPT	−0.64	0.84	−0.98	0.34	1.25	0.11
ALDR(%)	−0.11	0.50	−0.15	0.29		
AQUAT(HA)	0.086	0.66	0.14	0.52		
ERIC(HA)	−0.24	0.56	−0.16	0.73		
EMERG(HA)	0.61	0.081	0.59	0.081		
OPEN(%)	0.0099	0.33	0.013	0.19		
AREA	0.13	0.14	0.14	0.16	0.22	0.0067
IWDIST	−0.00049	0.52	−0.0013	0.065	−0.0011	0.082
LFDINDX	0.31	0.49	0.068	0.87		
RDDIST	−0.00034	0.41	0.0000076	0.98		
SWIINDX	0.16	0.48	−0.038	0.84		
PH	0.21	0.72				
COND	−0.065	0.049			−0.044	0.0067
Likelihood ratio		0.62		0.46		0.61
CCR[b] unused (%)	84		84		76	
CCR used (%) 86	84		80			
CCR overall (%)	85		84		78	

[a] *P*-values from models >0.56 predicted wetland use.

[b] Correct classification rate.

Table A-8. *Bald eagle* (Haliaeetus leucocephalus)[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−91.45	0.15	0.95	0.69	−2.54	0.0001
AQUAT(%)	0.42	0.15	0.06	0.080		
ERIC(HA)	2.27	0.14	−0.02	0.95	−0.20	0.031
EMERG(HA)	9.60	0.13	0.99	0.058	0.44	0.0044
OPEN(%)	−0.0094	0.89	−0.015	0.55		
AREA	−2.78	0.11	−0.12	0.55		
IWDIST	−0.012	0.30	−0.0058	0.18		
LFDINDX	−16.74	0.13	−2.16	0.039		
RDDIST	−0.028	0.15	−0.0027	0.035		
PH	22.54	0.14				
COND	−1.03	0.14				
Likelihood ratio		0.99		0.99		0.65
CCR[b] unused (%)	92		92		89	
CCR used (%) 91	91		73			
CCR overall (%)	92		92		87	

[a] *P*- values from models >0.18 predicted wetland use.

[b] Correct classification rate.

Table A-9. *Northern harrier* (Circus cyaneus).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−26.76	0.014	−7.70	0.00090	−3.01	0.0001
ALDR(HA)	−6.86	0.096	−4.90	0.20		
AQUAT(%)	0.091	0.0062	0.052	0.0080	0.023	0.022
ERIC(HA)	0.67	0.037	0.48	0.10		
EMERG(HA)	1.034	0.024	0.69	0.05	0.21	0.021
OPEN(%)	0.084	0.0054	0.048	0.012		
AREA	−0.21	0.068	−0.13	0.20		
IWDIST	−0.00018	0.85	0.00021	0.82		
LFDINDX	1.54	0.025	1.21	0.026		
RDDIST	−0.00029	0.58	−0.00018	0.71		
SWIINDX	−0.15	0.62	−0.033	0.90		
PH	2.53	0.052				
COND	−0.0085	0.53				
Likelihood ratio		0.99		0.99		0.97
CCR[b] unused (%)	83		80		77	
CCR used (%)	85		75		58	
CCR overall (%)	85		79		75	

[a] *P*- values from models >0.14 predicted wetland use.

[b] Correct classification rate.

Table A-10. *Virginia rail (*Rallus limicola*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−5.64	0.68	−3.10	0.25	−5.38	0.0001
ALDR(HA)	−2.64	0.23	−1.83	0.31		
AQUAT(HA)	−0.13	0.78	0.033	0.94		
ERIC(HA)	1.04	0.13	1.012	0.13	0.63	0.020
EMERG(HA)	0.037	0.92	0.14	0.67	0.26	0.026
OPEN(%)	−0.055	0.16	−0.042	0.18		
AREA	0.21	0.42	0.13	0.56		
IWDIST	0.0052	0.049	0.0042	0.021	0.0026	0.024
LFDINDX	−0.71	0.61	−0.78	0.57		
RDDIST	−0.0043	0.12	−0.0038	0.12		
SWIINDX	0.057	0.93	0.11	0.84		
PH	0.60	0.80				
COND	−0.033	0.45				
Likelihood ratio		0.99		0.99		0.99
CCR[b] unused (%)	90		100		86	
CCR used (%)	88		13		75	
CCR overall (%)	90		92		85	

[a] *P*-values from models >0.09 predicted wetland use.

[b] Correct classification rate.

Table A-11. *Sora (*Porzana carolina*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−0.18	0.97	−2.63	0.082	−1.08	0.017
ALDR(HA)	−1.44	0.21	−1.50	0.21		
AQUAT(%)	0.010	0.48	0.012	0.41		
ERIC(HA)	0.23	0.43	0.24	0.41		
EMERG(HA)	0.21	0.28	0.20	0.28	0.20	0.037
OPEN(%)	−0.032	0.042	−0.033	0.039	−0.024	0.033
SHOREDEV	0.00018	0.64	0.00020	0.59		
IWDIST	0.0013	0.11	0.0011	0.15		
LFDINDX	0.52	0.32	0.46	0.38		
RDDIST	−0.0011	0.069	−0.0010	0.079		
SWIINDX	0.33	0.42	0.27	0.49		
PH	−0.37	0.62				
COND	−0.0072	0.72				
Likelihood ratio		0.92		0.94		0.68
CCR[b] unused (%)	78		72		64	
CCR used (%)	83		89		78	
CCR overall (%)	79		76		67	

[a] *P*-values from models >0.21 predicted wetland use.

[b] Correct classification rate.

Table A-12. *Spotted sandpiper* (Actitis macularia).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−1.17	0.69	−0.26	0.79	−0.97	0.0023
ALDR(HA)	−2.66	0.075	−2.41	0.086	−1.12	0.022
AQUAT(HA)	0.28	0.30	0.23	0.33		
ERIC(HA)	1.075	0.19	0.94	0.22		
EMERG(HA)	−0.21	0.13	−0.21	0.13		
OPEN(%)	−0.0042	0.65	−0.0042	0.63		
AREA	0.15	0.065	0.14	0.066	0.15	0.00060
IWDIST	−0.0010	0.14	−0.00079	0.22		
LFDINDX	−0.029	0.94	0.092	0.80		
RDDIST	0.000010	0.97	−0.000051	0.89		
SWIINDX	−0.14	0.48	−0.090	0.63		
PH	0.12	0.80				
COND	0.0094	0.33				
Likelihood ratio		0.16		0.15		0.080
CCR[b] unused (%)	81		85		85	
CCR used (%)	75		67		63	
CCR overall (%)	78		77		75	

[a] *P*-values from models >0.46 predicted wetland use.

[b] Correct classification rate.

Table A-13. *Common snipe* (Gallinago gallinago).[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	−4.09	0.31	−2.96	0.015	−1.92	0.0001
ALDR(HA)	−1.65	0.20	−1.46	0.22		
AQUAT(HA)	−0.21	0.32	−0.20	0.30		
ERIC(HA)	2.33	0.081	2.07	0.10	1.49	0.06
EMERG(HA)	1.02	0.011	1.02	0.0084	1.05	0.0002
OPEN(%)	−0.019	0.12	−0.017	0.15		
SHOREDEV	0.00029	0.52	0.00018	0.67		
IWDIST	0.00036	0.64	0.00048	0.50		
LFDINDX	−0.15	0.78	−0.0099	0.98		
RDDIST	0.00025	0.53	0.00014	0.71		
SWIINDX	0.41	0.22	0.48	0.13		
PH	0.15	0.82				
COND	0.0088	0.15				
Likelihood ratio		0.77		0.73		0.27
CCR[b] unused (%)	80		78		82	
CCR used (%)	76		76		73	
CCR overall (%)	78		77		78	

[a] *P*-values from models >0.42 predicted wetland use.

[b] Correct classification rate.

Table A-14. *Herring gull (*Larus argentatus*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	3.27	0.54	2.71	0.08	1.40	0.0069
ALDR(%)	–0.27	0.53	–0.27	0.53		
AQUAT(HA)	0.15	0.38	0.16	0.37		
ERIC(%)	0.029	0.35	0.029	0.35		
EMERG(HA)	0.12	0.27	0.12	0.24		
TIMB(%)	–0.088	0.24	–0.087	0.24		
OPEN(HA)	0.055	0.34	0.055	0.34	–0.0040	0.0031
IWDIST	–0.0046	0.0070	–0.0046	0.0055		
LFDINDX	–0.51	0.51	–0.51	0.50		
RDDIST	0.00013	0.79	0.00012	0.80		
SWIINDX	–0.22	0.35	–0.22	0.34		
MARINE	–0.11	0.020	–0.11	0.0046	–0.082	0.0058
PH	–0.087	0.91				
COND	0.00059	0.96				
Likelihood ratio		0.94		0.96		0.99
CCR[b] unused (%)	82		84		16	
CCR used (%)	88		88		100	
CCR overall (%)	84		85		41	

[a] *P*-values from models >0.30 predicted wetland use.
[b] Correct classification rate.

Table A-15. *Belted kingfisher (*Ceryle acylon*)*.[a]

	Full		Habitat		Reduced	
Parameter	Estimate	*P*	Estimate	*P*	Estimate	*P*
INTERCEPT	9.35	0.11	1.52	0.23	1.35	0.0053
ALDR(%)	–0.0077	0.71	–0.017	0.38		
AQUAT(HA)	3.63	0.18	3.68	0.18	5.41	0.085
ERIC(HA)	–0.38	0.29	–0.33	0.33		
EMERG(HA)	–0.019	0.95	–0.071	0.79		
OPEN(%)	0.0090	0.50	0.0073	0.56		
AREA	0.091	0.46	0.087	0.49		
IWDIST	–0.0012	0.21	–0.00082	0.33	–0.00086	0.20
LFDINDX	0.33	0.58	0.22	0.71		
RDDIST	0.00022	0.74	–0.00025	0.66		
SWIINDX	–0.14	0.60	–0.17	0.49		
PH	–1.53	0.14				
COND	0.038	0.15				
Likelihood ratio		0.97		0.96		0.99
CCR[b] unused (%)	92		92		92	
CCR used (%)	72		63		58	
CCR overall (%)	74		65		62	

[a] *P*-values from models >0.85 predicted wetland use.
[b] Correct classification rate.

Appendix B. Observation and Measurement Data by Wetland Within the Study Areas

Baseline information on physical and chemical characteristics and bird use of study wetlands (see Table 1 and Methods for definitions of variable mnemonics and units of measure).

Table B-1. *Wetland name, location (Universal Transverse Mercator [UTM]), wetland area (AREA), and percent of wetland surface water in different vegetative life-forms. Study areas are as follows: DIX = Monroe–Dixmont, MSHR = Moosehorn National Wildlife Refuge, and BC = Beddington–Cherryfield.*

Wetland Name	UTM	Study Area	AREA	% ALDR	% AQUAT	% EMERG	% ERIC	% OPEN	% TIMB
BUTMAN POND	913491	DIX	7.42	0	23	10	0	0	67
CHAPMAN POND	965470	DIX	2.45	0	0	7	5	0	88
CHASE–LOWER	940461	DIX	9.58	26	14	6	24	0	30
CHASE–UPPER	952464	DIX	60.46	10	1	4	18	56	11
CROXFORD FLO	925481	DIX	1.68	0	36	0	0	0	64
DRAKE BC	889450	DIX	2.21	0	15	48	0	30	7
DRAKE D	888452	DIX	5.46	21	0	0	0	49	30
DRAKE–LOWER	891438	DIX	16.46	0	49	5	5	0	41
DRAKE–UPPER	889446	DIX	5.62	3	28	29	3	0	37
FEDERAL DCKP	945438	DIX	2.33	9	0	0	0	27	64
GILMORE MDWS	993484	DIX	5.74	7	3	65	0	0	25
GR FARM BK F	902397	DIX	0.25	0	5	32	0	0	63
JACOBIE I	988434	DIX	0.99	0	0	29	18	0	53
JORDAN BK FL	980475	DIX	1.00	76	0	1	0	0	23
LILY POND	970458	DIX	5.96	4	5	28	12	0	51
MASON HILL F	907387	DIX	0.76	10	0	16	10	0	64
NEW BEAV UPR	881424	DIX	2.03	27	0	0	0	67	6
NO TRESPASS	892407	DIX	2.36	0	32	61	0	0	7
OLNEY BROOK	919450	DIX	1.40	0	0	5	5	0	90
PERS BOG–UPR	902433	DIX	3.01	0	30	62	0	0	8
PERS MDW–LOW	907417	DIX	0.62	0	80	10	10	0	0
PETRO FLOW	915375	DIX	3.53	48	0	30	15	5	2
POWERLINE PD	899481	DIX	0.56	0	20	15	0	0	65
STATE DCKPD	982456	DIX	3.37	0	50	29	0	0	21
VAN DYKE SWP	986441	DIX	3.40	98	0	0	0	0	2
YORK–UPPER	983452	DIX	0.42	0	22	61	0	0	17
BARN MEADOW LOW	340003	MSHR	15.99	0	0	46	47	0	7
BARN MEADOW MID	350005	MSHR	7.04	6	1	93	0	0	0
BARN MEADOW UPP	356996	MSHR	6.68	4	20	47	6	0	23
BEARCE BROOK FL	314992	MSHR	0.33	1	3	67	0	0	29
BEARCE FLOWAGE	309920	MSHR	16.58	0	1	35	0	3	61
BEARCE LAKE	318930	MSHR	24.67	0	2	2	0	0	96
BOUNDARY FLOW	374989	MSHR	3.43	0	32	63	0	0	5
CONIC FLOW	324967	MSHR	3.47	0	14	84	1	0	1
CONIC LAKE	313953	MSHR	15.20	0	11	9	1	0	79
CRANBERRY LAKE	336924	MSHR	30.56	3	0	37	18	0	42
CRANBERRY OUT	341922	MSHR	4.35	0	0	81	0	1	18

Table B-2. *Continued.*

Wetland Name	UTM	Study Area	% AREA	% ALDR	% AQUAT	% EMERG	% ERIC	% OPEN	% TIMB
CROSSMAN FLOW	311940	MSHR	4.13	4	3	67	1	12	13
DALY FLOW	348910	MSHR	4.83	0	0	73	4	1	22
DUDLEY SWAMP S	340973	MSHR	0.86	0	10	86	0	0	4
DUDLEY SWAMP W	342977	MSHR	0.62	0	58	42	0	0	0
EATON HEATH	366942	MSHR	2.27	4	5	42	10	18	21
FIREHOLE	335915	MSHR	2.15	0	0	92	0	0	8
GOODALL HEATH LO	368982	MSHR	5.94	1	58	40	1	0	0
GOODALL HEATH UP	371977	MSHR	3.29	0	5	19	31	19	26
MACDOUGALL FLOW	368996	MSHR	2.68	0	0	46	0	0	54
MACK BROOK FLOW	325893	MSHR	0.62	0	0	0	0	0	100
MAGWOCK LOW	344009	MSHR	6.25	0	0	33	22	0	45
MAGWOCK MID	350006	MSHR	30.07	0	1	72	1	0	26
MAGWOCK UPP	355996	MSHR	18.99	0	0	43	0	0	57
MAHAR FLOW	347906	MSHR	1.34	0	0	7	0	0	93
MCGLAUFLIN MARSH	332993	MSHR	1.53	0	30	70	0	0	0
MILE BRIDGE FLOW	352935	MSHR	4.45	0	59	9	0	2	30
POPPLE FLOW	371987	MSHR	10.10	0	58	31	0	1	0
SNARE MEADOW	377926	MSHR	3.66	0	0	47	0	24	29
SO RIDGE FLOW	355908	MSHR	0.54	3	0	73	0	9	15
TWO MILE MEADOW	338965	MSHR	6.44	1	0	74	0	1	24
VOSE POND	377985	MSHR	23.85	0	19	8	1	0	72
ANDERSON POND	745449	BC	4.55	0	3	0	0	0	100
BFA FLOWAGE	693443	BC	3.45	0	78	22	0	78	0
CROOKED POND	863756	BC	1.86	0	88	88	0	0	12
CROOKED RIVERBW	868753	BC	5.25	0	100	0	0	0	93
DOWNING BOG	771443	BC	117.12	0	42	21	46	6	6
FOX POND	703425	BC	23.91	0	3	0	0	0	97
FOXTIT POND	697428	BC	1.19	0	49	6	45	0	0
FUELOIL POND	899743	BC	0.64	0	0	92	8	0	0
GILL BOG	689422	BC	1.32	0	9	0	0	0	91
HATCHERY POND	747412	BC	4.39	0	100	31	0	0	0
HOTDOG POND	680434	BC	2.89	0	56	0	0	0	94
KEROSENE POND	895746	BC	2.62	0	24	0	0	0	100
LILY LAKE	886715	BC	11.60	0	1	1	0	0	99
LITTLE LONG POND	730438	BC	21.75	0	2	1	0	0	99
LITTLEA FLOWAGE	693438	BC	0.65	0	0	28	0	72	0
MUD POND	722433	BC	1.60	0	17	1	0	0	98
MYRICK POND	731457	BC	15.22	0	100	0	0	0	75
PEEP POND	873743	BC	14.38	0	11	0	6	0	83
PICKEREL EAST	896712	BC	4.35	0	42	3	2	0	59
PICKEREL LAKE	891713	BC	10.74	0	14	16	0	0	76
SALMON POND	899754	BC	3.96	0	8	0	0	0	93
SALMONT POND	725432	BC	2.45	0	3	3	0	0	97
SHILLALAH POND	688414	BC	12.76	0	82	15	3	0	18
SNAKE FLOWAGE	695436	BC	4.95	0	10	28	21	41	10
SOFT SHOULDER	902731	BC	0.02	0	0	0	0	0	100
SPRING RIVER ARM	765423	BC	10.10	0	16	78	0	0	6
TILDEN POND	735435	BC	12.26	0	1	2	0	0	97
TUNK STM POND	778411	BC	8.88	0	65	13	49	0	11
UNNAMED POND	714451	BC	4.68	0	100	0	3	0	5

Table B-2. *Wetland physical characteristics and water pH (PH) and conductivity (COND).*

POND	IWDIST	LFDINDX	RDDIST	SWIINDX	SHOREDEV	PH	COND
BUTMAN POND	1510	1.99	384	2.54	2455	6.80	67
CHAPMAN POND	1215	1.53	1136	2.55	1413	6.70	40
CHASE–LOWER	1093	2.41	604	4.26	4675	6.80	68
CHASE–UPPER	1144	2.44	1080	1.68	4622	6.80	54
CROXFORD FLO	1712	1.26	182	2.48	1138	7.10	65
DRAKE BC	227	1.57	1082	3.06	1613	7.00	78
DRAKE D	224	1.50	1225	3.00	2488	7.00	78
DRAKE–LOWER	943	1.67	795	4.68	6727	7.00	46
DRAKE–UPPER	433	2.23	1065	2.75	2315	6.70	45
FEDERAL DCKP	856	1.52	483	1.48	803	7.30	85
GILMORE MDWS	961	2.04	808	2.81	2383	6.40	64
GR FARM BK F	786	1.46	375	2.92	518	7.10	79
JACOBIE I	339	1.59	331	3.06	1078	6.40	26
JORDAN BK FL	955	0.92	121	1.64	581	6.90	60
LILY POND	1287	2.58	793	2.85	2463	7.00	41
MASON HILL F	928	2.19	86	2.88	889	7.00	56
NEW BEAV UPR	1617	1.50	373	1.78	900	7.00	111
NO TRESPASS	996	2.17	446	2.17	1181	7.00	102
OLNEY BROOK	708	1.88	1194	7.64	3205	6.80	82
PERS BOG–UPR	556	1.59	805	6.19	3804	6.80	49
PERS MDW–LOW	1145	1.41	662	4.00	1116	6.80	51
PETRO FLOW	1316	1.81	138	1.74	1160	6.70	33
POWERLINE PD	613	1.88	275	3.05	809	7.01	477
STATE DCKPD	612	0.44	356	1.82	1185	7.00	40
VAN DYKE SWP	645	1.00	100	1.53	1002	6.50	29
YORK–UPPER	470	1.01	465	2.11	485	6.90	56
BARN MEADOW LOW	95	1.47	80	1.77	2520	6.35	44
BARN MEADOW MID	0	3.57	0	5.00	10041	6.66	42
BARN MEADOW UPP	5	3.87	502	3.02	2768	6.57	49
BEARCE BROOK FL	5	1.75	0	3.11	628	6.54	29
BEARCE FLOWAGE	5	1.49	0	2.43	3510	6.48	28
BEARCE LAKE	5	1.55	415	3.00	5282	7.00	27
BOUNDARY FLOW	175	1.37	2011	1.15	760	7.09	30
CONIC FLOW	600	1.84	375	1.72	1140	6.41	34
CONIC LAKE	100	1.50	442	1.41	1949	7.17	36
CRANBERRY LAKE	5	1.67	1447	3.79	7425	6.78	28
CRANBERRY OUT	100	1.44	1207	2.01	1449	6.36	36
CROSSMAN FLOW	280	2.29	20	1.63	1177	6.61	36
DALY FLOW	5	2.01	482	2.18	1698	6.97	35
DUDLEY SWAMP S	100	1.52	1307	2.05	676	6.17	21
DUDLEY SWAMP W	5	0.81	1527	2.81	781	7.18	38
EATON HEATH	1295	2.96	1408	1.66	890	6.10	26
FIREHOLE	200	0.54	2089	1.63	848	6.95	36
GOODALL HEATH LO	45	1.67	1297	1.84	1683	6.88	31
GOODALL HEATH UP	5	2.16	1490	2.06	1323	6.81	36
MACDOUGALL FLOW	250	0.88	1450	3.48	2023	6.58	26
MACK BROOK FLOW	1120	0.00	820	4.04	1129	6.48	34
MAGWOCK LOW	20	1.28	5	7.86	6965	6.55	39
MAGWOCK MID	5	1.68	5	1.92	3734	6.34	28
MAGWOCK UPP	10	0.75	1127	4.53	6990	6.23	25
MAHAR FLOW	5	1.00	905	6.27	2570	7.17	39

Table B-2. *Continued.*

POND	IWDIST	LFDINDX	RDDIST	SWIINDX	SHOREDEV	PH	COND
MCGLAUFLIN MARSH	550	1.00	30	1.55	679	6.17	45
MILE BRIDGE FLOW	240	1.99	1100	3.94	2943	6.21	31
POPPLE FLOW	140	0.87	1580	2.20	2489	6.96	27
SNARE MEADOW	412	1.32	1287	1.79	1217	6.36	28
SO RIDGE FLOW	260	1.99	1447	2.63	687	6.52	44
TWO MILE MEADOW	250	2.00	1529	1.96	1760	6.55	25
VOSE POND	190	1.73	2131	2.84	4930	6.84	29
ANDERSON POND	867	0.00	3102	1.28	972	6.00	18
BFA FLOWAGE	209	1.00	1096	1.68	1110	5.90	23
CROOKED POND	1	1.00	4014	2.00	971	6.60	19
CROOKED RIVERBW	1	0.81	3143	6.47	5659	5.60	19
DOWNING BOG	992	2.21	2570	2.85	10936	5.10	18
FOX POND	10	1.79	1	3.99	3394	6.20	39
FOXTIT POND	10	1.52	1	1.75	679	5.80	33
FUELOIL POND	139	1.00	60	2.89	823	5.00	38
GILL BOG	1	0.97	609	5.51	2245	6.00	33
HATCHERY POND	1	0.72	196	2.62	1947	5.70	24
HOTDOG POND	608	1.00	241	1.88	1138	5.40	16
KEROSENE POND	139	0.00	521	1.13	648	4.40	22
LILY LAKE	275	0.81	478	1.47	1783	6.00	19
LITTLE LONG POND	159	1.00	1151	1.80	2984	5.60	23
LITTLEA FLOWAGE	1	1.00	699	1.45	418	5.20	24
MUD POND	180	1.58	921	1.24	559	4.60	23
MYRICK POND	867	0.99	3147	5.69	3413	5.20	22
PEEP POND	321	4.36	2621	1.53	2064	6.10	13
PICKEREL EAST	99	3.27	134	1.51	1120	6.40	48
PICKEREL LAKE	275	1.44	254	1.28	1625	6.70	46
SALMON POND	697	1.00	990	1.18	835	4.90	16
SALMONT POND	180	0.91	865	1.13	633	6.20	22
SHILLALAH POND	1	1.90	1309	1.79	2250	6.00	30
SNAKE FLOWAGE	1	1.95	495	1.57	1245	5.40	22
SOFT SHOULDER	1074	0.00	63	1.96	89	5.60	37
SPRING RIVER ARM	1	1.41	1640	2.20	2488	6.00	27
TILDEN POND	159	1.14	1295	1.25	1563	6.40	22
TUNK STM POND	285	1.76	223	1.30	1375	6.00	27
UNNAMED POND	1516	1.40	2197	2.88	2215	5.30	22

Table B-3. *Effort (h) expended and sighting frequency of the pied-billed grebe (PG), common loon (CL), herring gull (HG), double-crested cormorant (DC), American bittern (AB), great blue heron (GBLH), and green-backed heron (GBKH).*

		Individuals per 100-h observation						
POND	EFFORT	PG	CL	HG	DC	AB	GBLH	GBKH
BUTMAN POND	54.1	20	6	0	0	48	17	4
CHAPMAN POND	22.9	0	0	0	0	4	0	0
CHASE–LOWER	70.2	3	0	0	0	20	1	0
CHASE–UPPER	104.0	17	0	0	0	20	1	0
CROXFORD FLO	41.6	0	0	0	0	5	0	0
DRAKE BC	20.3	0	0	0	0	5	5	0
DRAKE D	33.3	0	0	0	0	0	0	0
DRAKE–LOWER	53.0	68	2	0	0	51	11	0
DRAKE–UPPER	34.2	9	0	0	0	15	9	0
FEDERAL DCKP	23.4	0	0	0	0	0	9	0
GILMORE MDWS	43.4	0	0	0	0	30	7	0
GR FARM BK F	13.4	0	0	0	0	0	0	0
JACOBIE I	17.5	0	0	0	0	0	6	0
JORDAN BK FL	24.2	0	0	0	0	4	0	17
LILY POND	21.3	0	0	0	0	0	0	0
MASON HILL F	10.4	0	0	0	0	10	0	0
NEW BEAV UPR	26.5	0	0	0	0	4	0	0
NO TRESPASS	42.1	0	0	0	0	7	5	0
OLNEY BROOK	22.8	0	0	0	0	0	0	0
PERS BOG–UPR	27.7	0	0	0	0	4	4	0
PERS MDW–LOW	22.5	0	0	0	0	31	4	0
PETRO FLOW	10.3	0	0	0	0	0	0	0
POWERLINE PD	14.7	0	0	0	0	14	14	0
STATE DCKPD	47.6	0	0	0	0	4	4	0
VAN DYKE SWP	49.9	0	0	0	0	0	2	0
YORK–UPPER	9.7	0	0	0	0	10	0	0
BARN MEADOW LOW	29.3	0	0	14	0	3	34	3
BARN MEADOW MID	59.8	0	0	0	0	3	18	0
BARN MEADOW UPP	72.6	0	0	6	0	12	45	0
BEARCE BROOK FLO	9.3	0	0	0	0	0	11	0
BEARCE FLOWAGE	66.3	2	8	2	0	0	17	0
BEARCE LAKE	13.1	0	23	0	0	0	0	0
BOUNDARY FLOW	37.6	0	3	16	0	13	32	0
CONIC FLOW	23.9	0	0	8	0	0	21	0
CONIC LAKE	15.8	0	25	6	0	0	38	0
CRANBERRY LAKE	79.7	0	6	3	0	0	3	0
CRANBERRY OUT	25.1	0	0	8	0	0	12	0
CROSSMAN FLOW	61.7	0	0	0	0	0	3	3
DALY FLOW	49.8	0	0	4	2	6	10	0
DUDLEY SWAMP S	15.5	0	0	0	0	6	0	0
DUDLEY SWAMP W	22.2	0	0	9	0	0	9	0
EATON HEATH	21.8	0	5	0	0	5	14	0
FIREHOLE	10.5	0	0	0	0	0	0	0
GOODALL HEATH LO	48.1	58	0	6	2	31	33	0
GOODALL HEATH UP	39.1	3	0	3	0	10	15	0
MACDOUGALL FLOW	21.1	0	0	5	0	14	52	0
MACK BROOK FLOW	11.8	0	8	0	0	0	25	0

Table B-3. *Continued.*

	Individuals per 100-h observation							
POND	EFFORT	PG	CL	HG	DC	AB	GBLH	GBKH
MAGWOCK LOW	22.9	0	0	9	4	17	48	0
MAGWOCK MID	111.5	1	1	14	10	4	49	0
MAGWOCK UPP	97.0	0	2	15	1	2	37	0
MAHAR FLOW	20.4	0	0	0	0	5	10	0
MCGLAUFLIN MARSH	10.3	0	0	0	0	0	0	0
MILE BRIDGE FLOW	37.4	3	0	0	0	11	29	0
POPPLE FLOW	67.6	1	0	3	0	3	31	0
SNARE MEADOW	37.2	0	3	0	0	19	0	0
SO RIDGE FLOW	15.7	0	6	0	0	0	13	0
TWO MILE MEADOW	18.7	0	5	0	0	11	16	0
VOSE POND	23.7	0	30	13	4	0	25	0
ANDERSON POND	33.0	0	3	3	0	0	9	0
BFA FLOWAGE	48.0	0	0	0	0	2	0	0
CROOKED POND	27.0	0	7	0	0	4	0	0
CROOKED RIVERBW	42.0	5	14	0	0	19	0	0
DOWNING BOG	443.0	26	0	0	25	13	12	0
FOX POND	46.0	0	72	7	17	0	9	0
FOXTIT POND	34.0	0	6	0	0	0	24	3
FUELOIL POND	27.0	0	0	0	0	0	4	0
GILL BOG	33.0	0	6	3	0	0	12	0
HATCHERY POND	41.0	0	15	20	0	2	83	0
HOTDOG POND	35.0	0	6	0	0	0	9	0
KEROSENE POND	32.0	0	0	0	0	0	0	0
LILY LAKE	28.0	0	21	0	0	0	7	0
LITTLE LONG POND	48.0	0	52	2	13	0	2	0
LITTLEA FLOWAGE	39.0	0	8	0	0	0	3	0
MUD POND	27.0	0	0	0	0	0	0	0
MYRICK POND	35.0	3	29	0	11	0	14	0
PEEP POND	27.0	0	63	0	0	4	0	0
PICKEREL EAST	33.0	0	6	0	0	3	0	0
PICKEREL LAKE	33.0	0	21	0	3	0	6	0
SALMON POND	44.0	0	0	0	0	0	0	0
SALMONT POND	22.0	0	0	0	0	0	0	0
SHILLALAH POND	34.0	0	29	3	9	0	29	0
SNAKE FLOWAGE	62.0	0	8	0	0	13	5	0
SOFT SHOULDER	11.0	0	0	0	0	0	0	0
SPRING RIVER ARM	30.0	0	7	27	7	0	60	0
TILDEN POND	24.0	0	42	0	0	0	0	0
TUNK STM POND	84.0	10	1	2	25	11	20	0
UNNAMED POND	47.0	0	4	0	4	2	23	0

Table B-4. *Sighting frequency of the Virginia rail (VR), sora (SO), common snipe (CS), spotted sandpiper (SS), northern harrier (NH), bald eagle (BE), osprey (OS), and belted kingfisher (BK).*

	Individuals per 100-h observation							
POND	VR	SO	CS	SS	NH	BE	OS	BK
BUTMAN POND	4	18	33	15	4	0	6	18
CHAPMAN POND	0	0	4	0	0	0	0	9
CHASE–LOWER	0	0	1	0	0	0	0	11
CHASE–UPPER	7	0	13	9	0	0	1	22
CROXFORD FLO	0	0	0	0	0	0	0	7
DRAKE BC	0	0	0	0	0	0	0	5
DRAKE D	0	0	0	0	0	0	0	3
DRAKE–LOWER	0	0	4	2	4	0	4	15
DRAKE–UPPER	0	0	9	0	0	0	3	32
FEDERAL DCKP	0	0	0	0	0	0	0	38
GILMORE MDWS	0	2	9	0	0	0	0	7
GR FARM BK F	0	0	0	0	0	0	0	15
JACOBIE I	0	0	0	0	0	0	0	11
JORDAN BK FL	4	8	0	0	0	0	0	12
LILY POND	0	0	0	0	0	0	0	0
MASON HILL F	0	0	0	0	0	0	0	0
NEW BEAV UPR	0	0	0	0	0	0	0	4
NO TRESPASS	0	0	0	2	0	0	0	24
OLNEY BROOK	0	0	0	0	0	0	0	0
PERS BOG–UPR	0	0	4	0	0	0	0	4
PERS MDW–LOW	4	9	0	0	0	0	0	31
PETRO FLOW	0	0	0	0	0	0	0	0
POWERLINE PD	0	0	54	7	0	0	0	14
STATE DCKPD	0	0	0	0	0	0	0	6
VAN DYKE SWP	0	0	0	0	0	0	0	0
YORK–UPPER	0	0	0	0	0	0	0	0
BARN MEADOW LOW	7	20	17	3	7	7	3	17
BARN MEADOW MID	0	20	17	0	0	0	2	3
BARN MEADOW UPP	0	6	11	1	4	0	6	17
BEARCE BROOK FL	0	0	0	0	0	0	11	0
BEARCE FLOWAGE	0	0	8	51	0	3	14	17
BEARCE LAKE	0	0	0	8	0	0	15	15
BOUNDARY FLOW	0	0	3	21	0	0	3	3
CONIC FLOW	0	0	0	0	0	0	4	17
CONIC LAKE	0	0	0	19	0	0	25	25
CRANBERRY LAKE	0	0	19	9	0	0	13	0
CRANBERRY OUT	0	0	4	0	0	0	64	8
CROSSMAN FLOW	0	0	2	0	0	0	6	16
DALY FLOW	0	2	10	2	0	2	2	42
DUDLEY SWAMP S	0	0	6	0	0	0	0	0
DUDLEY SWAMP W	0	5	14	0	0	0	0	0
EATON HEATH	0	0	0	5	0	0	5	14
FIREHOLE	0	0	0	0	0	0	0	0
GOODALL HEATH LO	0	0	2	2	0	2	8	6
GOODALL HEATH UP	0	0	3	10	0	0	0	10
MACDOUGALL FLOW	0	0	5	5	5	0	0	28
MACK BROOK FLOW	0	0	0	0	0	0	0	17
MAGWOCK LOW	0	9	35	9	0	22	17	9

Table B-4. *Continued.*

	Individuals per 100-h							
POND	VR	SO	CS	SS	NH	BE	OS	BK
MAGWOCK MID	2	4	25	0	3	15	17	5
MAGWOCK UPP	0	3	7	0	0	8	11	4
MAHAR FLOW	0	0	15	25	0	0	10	25
MCGLAUFLIN MARSH	0	19	10	0	0	0	0	0
MILE BRIDGE FLOW	0	3	11	0	0	0	5	37
POPPLE FLOW	0	0	3	15	0	1	19	10
SNARE MEADOW	0	0	16	5	0	0	3	30
SO RIDGE FLOW	0	0	0	0	0	0	0	6
TWO MILE MEADOW	0	0	11	16	0	0	5	5
VOSE POND	0	0	0	21	0	0	13	17
ANDERSON POND	0	0	0	0	0	0	12	48
BFA FLOWAGE	0	0	0	0	0	0	0	8
CROOKED POND	0	0	0	4	7	0	4	30
CROOKED RIVERBW	0	0	0	0	5	0	2	24
DOWNING BOG	1	10	19	3	2	0	7	11
FOX POND	0	0	0	7	0	0	22	33
FOXTIT POND	0	0	0	6	0	0	3	41
FUELOIL POND	0	0	0	0	0	0	0	41
GILL BOG	0	0	0	3	0	0	3	21
HATCHERY POND	0	0	0	7	0	5	17	24
HOTDOG POND	0	0	0	0	3	0	6	6
KEROSENE POND	0	0	0	3	0	0	0	9
LILY LAKE	0	0	0	29	0	0	4	32
LITTLE LONG POND	0	0	0	4	0	0	6	19
LITTLEA FLOWAGE	0	0	0	0	0	0	3	18
MUD POND	0	0	0	0	0	0	7	7
MYRICK POND	0	0	0	14	0	0	20	54
PEEP POND	0	0	0	0	0	0	0	52
PICKEREL EAST	0	0	0	3	6	0	3	18
PICKEREL LAKE	0	0	0	6	9	0	6	21
SALMON POND	0	0	0	5	0	0	0	5
SALMONT POND	0	0	0	0	0	0	5	9
SHILLALAH POND	0	0	0	3	0	0	0	24
SNAKE FLOWAGE	0	15	2	0	0	0	0	39
SOFT SHOULDER	0	0	0	0	0	0	0	0
SPRING RIVER ARM	0	0	3	13	0	23	47	37
TILDEN POND	0	0	0	0	0	0	17	25
TUNK STM POND	1	2	1	1	0	7	7	31
UNNAMED POND	0	2	2	53	0	0	4	53

The following is a list of recent *Fish and Wildlife Research* publications.

1. Life History and Status of the Endangered Cui-ui of Pyramid Lake, Nevada, by G. Gary Scoppettone, Mark Coleman, and Gary A. Wedemeyer. 1986. 23 pp.
2. Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North American Wetlands, by Daniel Q. Thompson, Ronald L. Stuckey, and Edith B. Thompson. 1987. 55 pp.
3. Taxonomy, Life History, and Ecology of a Mountain Mahogany Defoliator, *Stamnodes animata* (Pearsall), in Nevada, by Malcolm M. Furniss, Douglass C. Ferguson, Kenneth W. Voget, J. Wayne Burkhardt, Arthur R. Tiedemann, and John L. Oldemeyer. 1988. 26 pp.
4. Demographic Characteristics of a Maine Woodcock Population and Effects of Habitat Management, by Thomas J. Dwyer, Greg F. Sepik, Eric L. Derleth, and Daniel G. McAuley. 1988. 29 pp.
5. Premigrational Movements and Behavior of Young Mallards and Wood Ducks in North-central Minnesota, by Ronald E. Kirby, Lewis M. Cowardin, and John R. Tester. 1989. 25 pp.
6. Water and Habitat Dynamics of the Mingo Swamp in Southeastern Missouri, by Mickey E. Heitmeyer, Leigh H. Fredrickson, and Gary F. Krause. 1989. 26 pp.
7. Chironomidae of the Southeastern United States: A Checklist of Species and Notes on Biology, Distribution, and Habitat, by Patrick L. Hudson, David R. Lenat, Broughton A. Caldwell, and David Smith. 1990. 46 pp.
8. Forest Bird Habitat Suitability Models and the Development of Habitat Models, by Beatrice Van Horne and John A. Wiens. 1991. 29 pp.

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FISH AND WILDLIFE SERVICE

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